LCC-3

Department of Defense

LIFE CYCLE COSTING GUIDE FOR SYSTEM ACQUISITIONS

(INTERIM)

JANUARY 1973

OFFICE OF THE SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

In 1970 we issued a Guide, LCC-1, and a Casebook, LCC-2, to assist in implementing the concept of life cycle costing in acquisitions of materiel below the level of complete systems. This Guide, LCC-3, is intended to assist in implementing the LCC concept in system acquisitions.

Program Managers and DoD contractors are generally aware that important system programs have been terminated simply because the anticipated cost was more than the DoD could afford, and this will occur again. Industry has been challenged to design to a price and, to date, the response has been favorable. The response to this challenge in the future will be an important element in the DoD-industry relationship.

In addition to unit production price, contracts on major systems increasingly will be made on the basis of life cycle costs and these costs will be an important ingredient in the decisions made by the DoD to continue a program, curtail it, or discontinue it. The DoD intends to improve cost-effectiveness of major systems and equipments with emphasis on reliability and maintainability being major considerations toward this end. Thus, contractors should be aware that full scale development and production contracts will be awarded on this basis and such contracts may not be awarded at all if acquisition and operating and support (O&S) costs are more than the DoD can afford.

Changes and modifications to these interim guidelines will be issued as experience is gained in the use of life cycle costing methodology in system acquisitions. Program Managers and others involved in system acquisitions are encouraged to submit suggestions for improving this Guide, based on their experience with it.

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PREFACE

LCC-3

DEPARTMENT OF DEFENSE

LIFE CYCLE COSTING GUIDE FOR SYSTEM ACQUISITIONS

(Interim)

This interim Guide presents guidelines, including representative detailed procedures, for applying the Life Cycle Costing concept during the acquisition of complete defense systems. The provisions of this Guide may also be used in acquisitions below the level of complete systems when deemed suitable.

Changes to these guidelines will be issued as experience is gained in their application and as useful progress is made in the development of relevant methodology. Proposals for changes or additions to the Guide should be forwarded through appropriate channels to the Office of the Assistant Secretary of Defense (Installations and Logistics)CM, Attention: Chairman, DoD Life Cycle Costing Steering Group, Pentagon, Washington, D. C. 20301.

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CHAPTER 1

INTRODUCTION

1.1 Definitions

a. The Life Cycle Cost (LCC). ~~The LCC~~ of a system is the total cost to the Government of acquisition and ownership of that system over its full life. It includes the cost of development, acquisition, operation, support and where applicable, disposal. However, in certain applications of this Guide, such as LCC estimation for purposes of contractual commitments, source selection and choices among design alternatives, LCC is generally used to examine only relevant costs.

b. System. For the purpose of this Guide, a complete system is defined as a major end item and all the components required for its operation and support, including relevant facilities, equipment, materiel, data, personnel and services. (Note: The Guide is applicable to hardware systems which are weapon systems, communication systems, etc.)

1.2 LCC and Economic Analysis (DoDI 7041.3).* The use of a total cost concept for certain important decisions is prescribed by DoD Instruction 7041.3, "Economic Analysis and Program Evaluation for Resource Management." Techniques for making credible estimates of

*October 18, 1972

such costs are covered in this Guide (LCC-3) with special emphasis on advancing the credibility and the use of operating and support (O&S) costs as part of the system acquisition process. This includes consideration of O&S costs as influences on design and other decisions involved in development and production.

1.3 Applications. LCC concepts should be used for decision-making during all stages of the system acquisition process, and these decisions are discussed in Chapter 2. In the early stages, the parametric method of developing Cost Estimating Relationships (CERs) is generally more suitable for this purpose. As the configuration of the system begins to harden, engineering costing techniques such as the model of Operating and Support (O&S) costs in Appendix I of this Guide should increasingly be used. The CER and engineering techniques are treated in Chapter 3.

LCC techniques will differ at various milestone points and phases of system acquisition. Differences in technique may also be necessary due to variations in the broad strategy and phasing of different systems, such as the determination of whether parallel prototyping will be accomplished. The variations between techniques used in different acquisition strategies are discussed in Chapter 4.

A primary intent is to cause LCC estimates to impact upon design/development decision-making by each bidder and contractor. To accomplish this intent each will have to be made fully aware, during the earliest development stages, of how the LCC of his design and system plans will be treated. He will also have to understand clearly that the LCC estimate will be a prime consideration in product evaluations, in source selection, and in program continuation. The contractual aspects of this are covered in Chapter 5.

Program Managers are encouraged to use considerable latitude in the application of this Guide, adapting it as needed to fit their circumstances.

1.4 Related Programs. There are many management systems, disciplines and technologies in use and under consideration in connection with system acquisition. These include Integrated Logistic Support, Reliability, Maintainability, Repair Level Analysis, Inventory Management, Spares Provisioning, Configuration Control, Management Information Systems, Systems Engineering, Value Engineering, Resource Conservation, Cost-Effectiveness, etc. Although these varied approaches have not always been treated in an integrated manner, at their very essence they are closely inter-related to each other. One of the interfaces at which these approaches often converge is their common involvement with the logistic support of operating systems, the costing of which through LCC forces these programs into a balanced relationship.

CHAPTER 2

LCC IN DECISION-MAKING

2.1 Virtually all decisions should be made taking life cycle cost into account. The two basic considerations that influence these decisions are life cycle cost and System Effectiveness. This Guide is concerned with the LCC aspects of the decision process.

2.2 <u>The Decisions Influenced by LCC</u>. The Government is attempting to build a system management process in which cost considerations, taken in conjunction with consideration of System Effectiveness and schedules, will properly influence virtually all decisions. Perhaps the most important decisions of all will be those made by the Defense Systems Acquisition Review Council (DSARC) governing the continuing viability of a system effort, i.e., whether to initiate it, and subsequently whether to discontinue it, or to remain in the existing Acquisition Phase, or to proceed to the following Phase(s). Other important decisions include the choice among alternatives in the following areas: contractual requirements, both qualitative and quantitative; hardware and software designs; proposed product improvement effort; preventive maintenance programs; corrective maintenance decisions such as throwaway versus repair of failed items (and the associated choice of level of repair); personnel; support systems; operating procedures -- in short, virtually anything that can influence the life cycle costs and/or effectiveness of the system.

Through realization that the provisions of this Guide will be applied in program evaluations, and sometimes in subsequent source selection(s), contractors will be motivated to use LCC analysis on all of the above kinds of decisions during all Acquisition Phases, even before LCC estimates are required as contractual commitments.

2.3 The Two Predominant Decision Considerations. When interpreted in its broadest sense, the phrase "cost-effectiveness analysis" conveys the major ideas which govern decision-making in system acquisition. In choosing among alternatives, the decision-maker should consider everything that will have to be paid in the future for each alternative as well as every future benefit or achieved objective that will result from each alternative. This includes, to the extent possible, costs in forms other than dollars (for example, commitment of such other resources as existing buildings or land, or such intangible costs as departure from a strong precedent), especially where they differ between alternatives. It also includes all possible types of benefits, both tangible and intangible, which may occur at any future time during the system's life cycle, including especially System Effectiveness. The term Life Cycle Costing (LCC) specifically denotes the inclusion of subsequent costs along with initial investment costs.

This Guide will say relatively little about the detailed tools for measurement and evaluation of System Effectiveness. By no means should it be inferred that Effectiveness is thereby being downgraded so far as it concerns the influence exerted over decisions in the LCC context. It is rather that this is a vast subject unto itself which is extensively treated in

System Effectiveness publications. (System Effectiveness is the analysis of a system potential and/or capacity to perform its assigned mission.) In this Guide, the central issue is the improved treatment of costs relevant to decision-making.

2.4 Sensitivity of Decisions to LCC. The impact of LCC is that its use will sometimes lead to a preference for a different decision than the one that would be made if cost consideration were limited to initial costs.

The LCC value, as estimated at any point during the acquisition process, may indicate that the total cost of the contemplated system is excessive in relation to the anticipated benefits. In such cases, the LCC consideration may lead to a program discontinuance, reduction, simplification, or replacement by an alternative approach.

A second type of impact is shown in Figure 2-1. This Figure illustrates a case in which Alternative A, with higher initial cost than Alternative B, leads to a flow of subsequent or "consequential" costs which are sufficiently smaller so that the total cost of A is lower than the total cost of B.

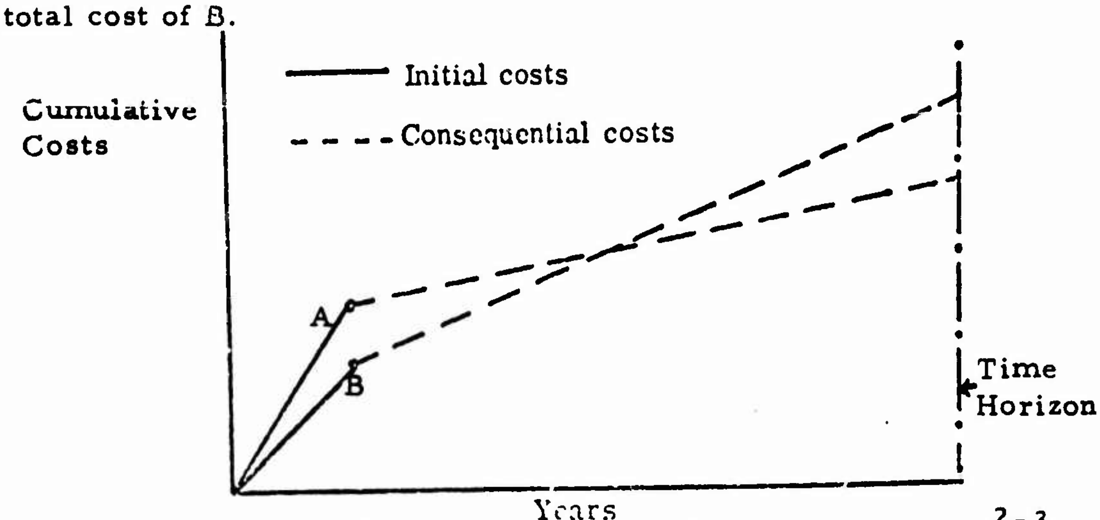

Figure 2-1. Cumulation of Costs over Time

Assuming that the benefits from both A and B are equal, use of the LCC approach will lead to choice of A for the "time horizon" shown, whereas without LCC the choice would be B. However, the choice of a higher initial cost item may sometimes be constrained by short term budgetary limitations, or by other considerations, e.g., manpower, real estate, or investment policies. In such cases, where it appears that the full advantage of LCC cannot be achieved within these constraints, the policy authority should be advised so that he may be afforded an opportunity to remove the constraint.

Selection of the time horizon can be a critical element of the LCC decision-process. This selection should be made carefully in each application, based on the expected or intended life or lives of the alternatives under consideration. The choice of the "time-horizon" will determine whether the cumulative cost lines cross during or after that life (if they cross at all). Equally important, the time horizon also influences the quantitative difference between the LCC values. (Refer to DoD Instruction 7041.3, Encl. 2, page 7, paragraph c., for direction in choosing the time horizon.) In the cost-effectiveness analysis, it is that quantitative difference in costs which is compared to a quantitative difference in effectiveness in order to help make decisions. (Note that the quantitative cost difference may be affected by the practice of discounting future costs to a "present value." This is covered more fully in DoDI 7041.3, Encl. 2, page 5, paragraph b.)

2.5 Tradeoffs. The use of LCC in decision-making is by no means limited to cases like the one above, wherein it was assumed that "the benefits are equal." If Alternatives A and B in the example above generate different benefit streams, with more benefits from B, then the choice between them comes back to cost-effectiveness analysis of whether B's extra benefits are worth the extra cost. This is the broadest kind of tradeoff which must ultimately be made. Many other tradeoffs must also be made at various levels of decision-making.

In general, there is no need to make tradeoffs if one choice "dominates" the alternative choices, in the sense that this choice is the better one by all the applicable criteria. Thus, if a decision affects only two criteria, and if Alternative A is preferred over Alternative B for each of the two criteria, then Alternative A can be chosen without any signs of having conducted a tradeoff, as A is dominant. For example, if consideration were being given to a new vehicle's range and its accuracy in delivering a payload, then no real tradeoff would be involved if A had both longer range and more accurate delivery than B. On the other hand, if A is superior in range while B is superior in accuracy, then a tradeoff is needed. This tradeoff, explicitly or implicitly, comprises a judgment on how many units of one criterion are equivalent to how many units of the second criterion.

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As an illustration, Figure 2-2 depicts choices involving two basic criteria, LCC and total System Effectiveness. In 2-2a, A is preferable to B because of lower LCC; in 2-2b, A is preferable to B because of higher System Effectiveness; in 2-2c, A dominates B by being superior in both criteria; in 2-2d, A would be judged preferable to B if its improved Effectiveness is deemed to be worth more than its extra Life Cycle Cost.

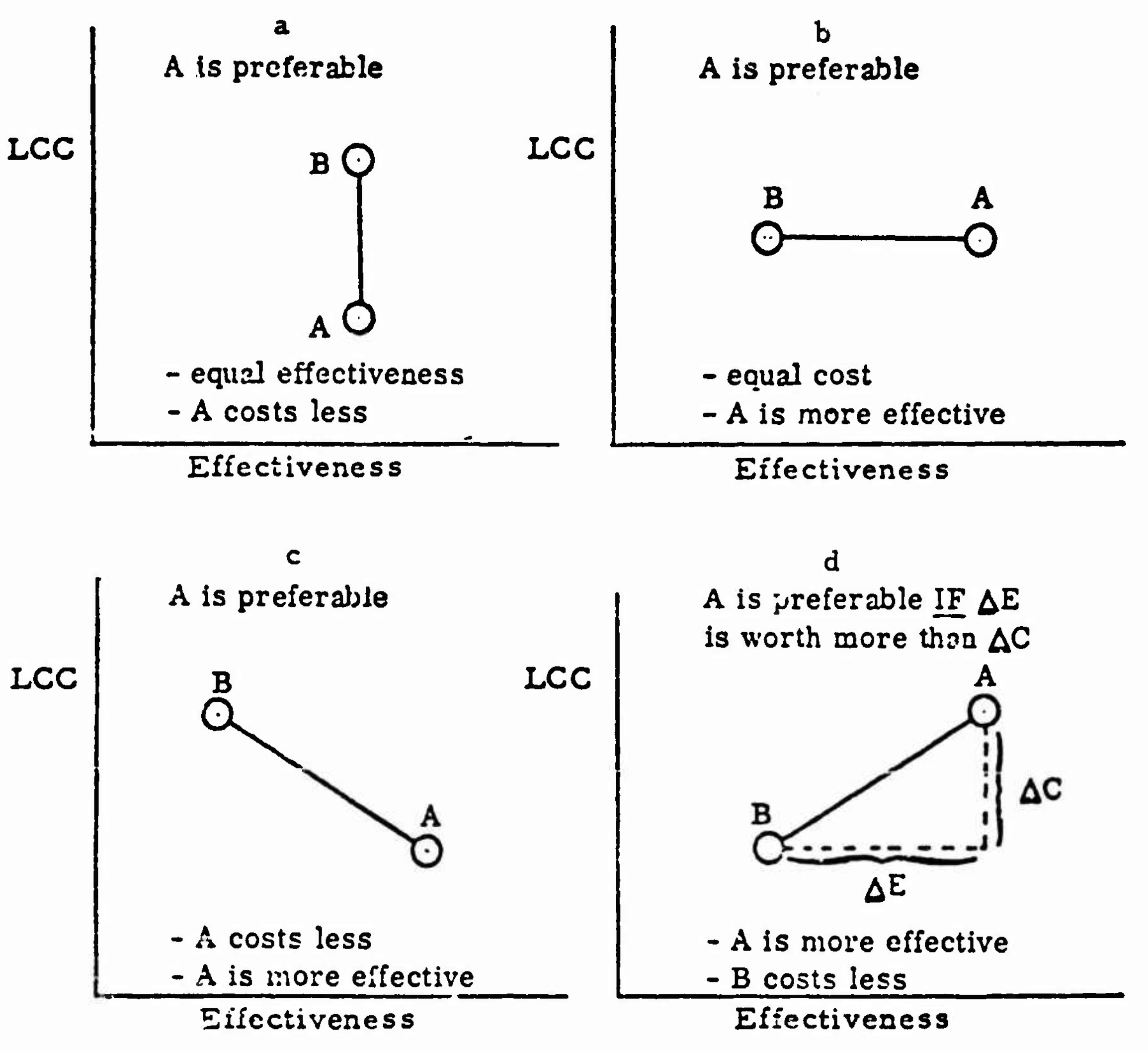

Figure 2-2. Choosing Between Alternatives

2.6 <u>Multiple Criteria and Common Units.</u> As the number and the diversity of tradeoff criteria increases, the determination of preferences between alternative choices, each of which gives one combination of the criteria, escalates in difficulty very rapidly. It is therefore necessary to manage the decision process so as to reduce to a minimum the number of criteria which influence the decision-making. This is most difficult when important criteria cannot easily be converted to common units, but should be pursued as far as possible whenever criteria can be measured in (or converted into, or incorporated within) common units. An example of this approach would be where the Government specifies overall performance requirements instead of detailed design specifications. The ultimate along these lines would be the conversion of everything possible to the minimum number of criteria, that is, to LCC and to System Effectiveness.

The use of dollars as one key measurement unit in this context does not imply an inordinate concern with economics or budgets at the expense of military security. Rather, the dollars serve as a measurement tool which provides a common medium of exchange and thus expedites "trading." This tends to replace a direct and cumbersome barter system, much the same as money does in the market place (where people no longer have to swap their butter for their shoes, etc.).

Present policy in system acquisition calls for tradeoffs to be conducted all through the development and production phases. The greatest flexibility is achieved, both in breadth of feasible tradeoffs and also over time (so that successive tradeoff re-examinations incur the least amount of reversal of prior conclusions), when very broad criteria are used. For example, if we fixed a requirement on a characteristic such as Reliability or Maintainability, a value for the complete weapon system would be preferable to a set of subsystem values. The former would make it easier to respond to newly obtained information, and would allow the revision of subsystem planning values without necessitating a change in the fixed requirement. Similarly, if overall requirements could be fixed in terms of total LCC and System Effectiveness, instead of in narrower terms, then the flexibility of continuing tradeoffs would be substantially improved.

2.7 Balance Between LCC and System Effectiveness. Consider a case in which this Guide is applied so that payments to the contractor will be affected by his demonstrated success with LCC, for example through an incentive clause. Such an arrangement could conceivably cause LCC considerations to become more influential than System Effectiveness unless steps are taken to preclude this undesirable development by also including, in the contract, balanced monetary arrangements which depend upon demonstration of success in System Effectiveness. In general, although LCC is intended to correct past underemphasis of recurring support costs, it must not be implemented in a way that will allow the "logistic tail to wag the dog," and tradeoffs between cost and effectiveness must be managed with the utmost care.

It is possible to think of System Effectiveness either in terms of an entire fleet or in terms of the effectiveness of individual vehicles (such as ships, or tanks, or aircraft). In the latter case, greater or lesser achievement per vehicle is almost certain to lead to comparably greater or lesser achievement at the level of the total fleet. It is also possible, however, that the fleet size will be adjusted instead. Thus, if each individual aircraft will be more available, or dependable, or capable, then a compensating reduction might be made in the number of aircraft to be procured. In this event, increased effectiveness of the individual aircraft will be reflected in terms of fleet LCC rather than fleetwide System Effectiveness, as the latter could be held constant. For this reason, an adaptation of this Guide could be so designed as to include performance "effectiveness per vehicle" under the LCC management framework. If the operational readiness per aircraft, for example, materializes at a different percentage than is contracted for, the incentive formula based on demonstration for LCC could reflect the cost of a revised number of aircraft so that the original contract for operationally ready hours would be met, regardless of whether fleet size will actually be adjusted to reflect the achieved operational readiness per aircraft.

CHAPTER 3

COST MODELS

3.1 This Chapter will attempt to classify variations in cost models to the extent needed by the reader of Chapter 4, wherein recommendations are made as to the kinds of models that should be used at various times and for various purposes in the system acquisition process.

3.2 <u>Definition.</u> A cost model comprises one or more mathematical relationships, arranged in a systematic sequence to formulate a cost methodology in which outputs (cost estimates) are derived from inputs (descriptions of the equipment, organization, procedures, etc.). Cost models can vary from a simple one-formula model to an extremely complex model that involves hundreds or even many thousands of calculations. As an example of a very simple cost model, the cost of an item might be related directly to its weight; that is,

$$C = DW,$$

where C = cost of item in dollars,

D = cost in dollars per pound of weight,

W = weight in pounds.

Here, D and W are inputs to the model and C is the output. Although this is a very simple model, it nevertheless performs the function of providing a cost estimate for given inputs.

Because the term "cost model" is used in various situations, it can have a variety of specific meanings. In all cases it is a device designed to obtain a cost estimate. In brief, it is a more or less abstract representation of a part of the real world based upon insights into the cause-and-effect relationships existing in that world.

There are various kinds of cost models. Life Cycle Cost models are distinguished from other cost models in that the former always reflect subsequent costs which are the direct consequence of the decision or action being contemplated, including operating and support (O&S) costs, rather than merely the initial costs. For example, in Figure 2-1, a Life Cycle Cost model will estimate the sum of the initial costs (solid line) and the consequential costs (dashed line), whereas most other models will estimate only the initial costs.

3.3 Applications of Cost Models. Cost models are structured to conform to specific categories, depending upon their intended use. Examples of these categories include breakdowns by organizational entities, program elements (FYDP), specific budget categories, functional elements, work breakdown structure (hardware applications) or special categories relating to investment decisions. This Guide will focus its attention on LCC models in categories which will assist decision-making during the acquisition process. Appendix I provides the O&S costs portion of such an LCC model for typical major systems.

3.4 <u>"Cost Estimating Relationship (CER)" Method.</u> If there are prior hardware systems which can be compared with the new (proposed) system, and if physical, performance, and cost data are available on the older systems, then statistical analysis may provide useful cost projections. Through curve-fitting techniques, system cost may be related to a combination of measures of the system (its dimensions, performance, etc.). Similarly, cost of some types of subsystems may be related to their physical and performance attributes. The relationships established are commonly called "Cost Estimating Relationships (CERs)." The method is sometimes called "Parametric Costing," because the physical and performance measures are commonly called parameters in the estimating equations.

Situations occur in which cost estimates are desired or required, but the information necessary for explicit CERs is unavailable. At such times highly subjective ("ball park") estimates are frequently made and can be justified as more useful than no estimate at all. Such estimates can reasonably be thought about as "Implicit CERs," inasmuch as the estimator is subconsciously (or at least not overtly) extrapolating from prior experience through use of an unformulated or vaguely conceived relationship of the new item to older items. Unless otherwise specified, references to CERs in this Guide mean explicit rather than implicit CERs.

An illustration of an explicit CER follows:

$$C = Ae^{B(\log V) - D}WRST,$$

where

C, the dependent variable, is airframe development and design cost;

e is the base of the natural logarithms;

A, B, and D are coefficients (rational numbers);

V = maximum aircraft velocity in knots at maximum power and 55,000 feet altitude;

W = airframe weight in tons;

R = the hourly pay rate of engineering manpower;

S is a factor which takes on either of two values, depending on whether the aircraft is fixed wing or variable sweep wing; and

T = the fraction of the airframe which is titanium.

CERs can be simpler or more complex than the one shown above. They can reflect total system development, production, and/or operating and support (O&S) costs. They can reflect individual segments of those costs or a composite of them all. The segments are usually large, and the number of independent variables (or parameters) is usually small. Most CERs used in past acquisitions have omitted O&S costs, or have included them only partially.

It should be remembered that use of the CER Method depends upon judgment that the historical data processed into a CER reflects sufficient commonality with the proposed new item being costed to give a reasonable cost estimate of the latter. Where the effects of inadequate commonality can be estimated, an adjustment may be made to the CER.

CERs are available for a wide variety of systems (e.g., aircraft, missiles, radars, ships, tanks, and trucks), and are used by research and development personnel and cost analysts in the pertinent hardware areas. No general catalog exists, and the equations in use are generally non-standard or even treated as proprietary company information.

Representative documents covering CER methodology and actual models are listed in Appendix III.

The CER Method has several advantages. First, it may be used early because it can be and usually is based on broad performance parameters and configuration concepts, rather than on detailed design. Generally, its use should start during the Concept Formulation Phase.

A second advantage is that, once developed, it is rapidly and inexpensively employed. Hence it can be used for numerous possible versions of the system.

Third, the CER Method is less susceptible to the motivational bias of its users than other costing methods. It is not wholly free of bias, because its general shape and the choice and values of some of its parameters may be subjectively determined. Its objectivity advantage is sufficient, however, to justify its continued use along with more detailed methods once such methods are possible.

A fourth advantage is that the CER Method can provide confidence intervals as well as expected values of cost. Of the variety of curve-fitting schemes that have been used for the derivation of CERs, regression analysis has been the most common so far, and has enabled ready computation of confidence intervals.

Along with the advantages come disadvantages, the first of which is that the method is not applicable to radically new systems. The statistical relationships used are derived from experience, and that experience must be relevant to the new system. Hence the new system must fit into an existing family of systems or be similar enough to such a family to justify use of the CER Method, perhaps with some adjustment. The CER Method consequently cannot produce reliable results for a system which depends heavily on new technology or incorporates drastically different design features.

A second disadvantage is that adjustments may be required even when the method is used on systems which are not radically different from their predecessors. There are economic trends, cost ratios, design practices, manufacturing methods, and O&S precepts which are not explicit parts of the CER and which are changing continually. They cause the relationship to become gradually less accurate and to need revision.

Third, when separate estimates are required for such system elements as built-in test equipment, fire power control, data, systems engineering, tooling, mock-ups, spares, replacement training, fuel, or pay and allowance of enlisted personnel, the method either fails or becomes like highly detailed methods of estimation which rely on much greater detailed information. It also becomes more expensive to use as finer details are to be separately costed, because of the need to develop additional CERs. Therefore, the CER Method is most generally applied in making development and design trade-offs at very high levels of aggregation. On the other hand, in the creation of detailed approaches to estimation under conditions where direct engineering or production cause-and-effect relationships are not known, or where cost inputs are not definitively known, CERs may be the best method for constructing some of the detailed submodels of the overall system cost model.

A fourth disadvantage of the CER Method is that most published work on CER models to date generally does not include O&S costs, except occasionally for operating manpower and fuel. The few which attempt broader coverage of O&S costs tend to have two weaknesses: (1) they reduce the feasibility of actually using them, by incorporating parameters which are difficult or impossible to cost; and (2) they involve so much detail that many specifics of design are required, thus making it necessary to defer their actual application until later phases of the acquisition process.

The lack of development of CERs for use in forecasting O&S costs has forced reliance on the use of implicit CERs for those costs until substantial design information is available. There seems no reason, however, to believe that aggregate O&S costs cannot in the future be estimated, even in early acquisition phases, through use of explicit CERs. Historical O&S cost data are gradually becoming adequate to support statistical studies for the establishment of useful relationships. Sources of O&S cost data are included in Appendix II.

3.5 The "Engineered Cost Estimate" Method.1/ As information about the hardware system and its use increases, and as the DoD approaches decisions committing progressively larger amounts of

1/ A pioneer document is PROJECT ABLE (Acquisition Based on Consideration of Logistic Effects), Irving Katz, May 1969, Operations Analysis Report No. 8, Hqs, AFLC. Defense Documentation Center No. AD 690-520.

money, more detailed Life Cycle Costing becomes warranted and also becomes progressively more feasible. Total system cost is anatomized into many elements, consisting of breakdown into finer details of hardware, functions, procedures, etc. The elements are related through cost equations which reflect in detail the way the elements interact when the system is developed, produced, operated, and supported. The equations are expected to reflect the real world so closely that they can be said to be "engineered." They differ from the equations used in the regression analysis which create CERs. The "engineered" equations follow more closely the step by step cause-and-effect relationships in a microscopic examination of the sequence of events in the real world. Regression analysis equations addressed to an identical cost aggregation deal with statistical patterns in more of a macroscopic approach and with less inherent capability to reflect departures from past conditions.

As an example of the above distinction, consider some past CER estimates which have taken the form that O&S costs equal a certain percentage (e.g., 225%) of production cost. An engineered estimate of those same O&S costs would be computed as illustrated in Appendix I, and the percentage relationship of O&S to production costs will vary widely from case to case.

The engineered cost equations are filled in with estimates of the values of the many elements. The estimates of the elements, their subtotals, and their totals are examined and revised, where the revisions reflect either improved knowledge of the anticipated costs or revised decisions based on continuing tradeoff analysis to make the system as cost-effective as possible. Such a process yields "Engineered Cost Estimates."

Generally, use of the Engineered Cost Estimate method becomes possible at about the same time it becomes needed from the standpoint of decision-making. Step by step, decisions on hardware and on operational and support concepts must be made, the timing of each being governed by leadtime considerations and prerequisite decisions in the overall acquisition process. As each decision is made, the latest (and presumably best) estimates are used concerning alternative implications for LCC and System Effectiveness. Thus, as will be further described in Chapter 4, there is a gradual transitioning from CERs to Engineered Cost Estimates rather than a single changeover point for the entire system. When there is enough knowledge of the system to warrant Requests for Proposals for Full Scale Development or for Production, there should be enough knowledge to analyze cost in detail. Prior to that time, the same unknowns that preclude a decision to proceed to these acquisition phases also preclude reliable estimation of costs.

There are numerous reasons for employing the Engineered Cost Estimate Method as soon as conditions for its use have been met.

One advantage is that it can be more accurate than CERs because it usually incorporates expert inputs at detailed levels. Different elements can be estimated by different people, and each element can be small enough to be within an individual's area of expertise and awareness of the latest information (such as test results, cost of proposed improvements, and so on).

A closely related advantage, as mentioned above, is that the Engineered Cost Estimate Method can be applied independently to the various parts of the system. Hence, for system segments on which firmer descriptive information is available at an earlier stage, this cost method can be used to adjust or replace the results of the CER Method.

Another advantage of the Engineered Cost Estimate Method is that it can contain enough detail to permit study of cost differences among competing functional proposals (for production, development, inspections, support procedures, etc.). Rules for use of the method should be clear and definite, so that proposals prepared accordingly can be compared. Sufficient specifics can be included that comparisons will illuminate specific functional areas and amounts of cost difference.

Fourth, the Engineered Cost Estimate Method allows more detailed simulation and sensitivity studies to be made, because it

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permits individual elements to be scrutinized and it allows costs to be regrouped in numerous ways.

Finally, as noted above with special reference to the operating and support (O&S) cost segment of LCC, CERs have generally estimated O&S in ways that make it vary in the same direction as development and production costs. The Engineered Cost Estimate, on the other hand, may properly reveal that certain increases in development and/or production costs (for example, those which reduce frequency of failure) will cause reductions in O&S costs -- in other words, they will vary in an inverse way rather than in the same direction.

As with other methods, there are also drawbacks. The Engineered Cost Estimate Method cannot serve effectively as the primary costing method until detailed information is at hand. By that time, certain prior decisions have already removed some of the latitude in considering alternatives which now appear attractive but are incompatible with actions already taken.

A second disadvantage of the Engineered Cost Estimate Method is that it is generally more costly and more time consuming than the CER Method. To have element estimates on a major system which are complete, up-to-date with new cost rates and design changes, and internally consistent can be a large assignment. Great care is warranted in avoiding excessive details, i.e., those whose impact on the system will be minor.

Potential difficulty of review and evaluation is a third disadvantage. There could be a tendency for cost models prepared by the Engineered Cost Estimate Method to become so large, complex, and detailed that they cannot be interpreted and compared within the time and resources available. Again, avoidance of low-impact details, as well as advance establishment of rules and procedures for element estimate summarization and verification is essential if this pitfall is to be avoided.

A fourth disadvantage is that the Engineered Cost Estimate Method is subjective in some cost inputs, and the effect of that subjectivity on reliability of subtotals and totals may be great. That drawback calls for careful review and credibility assessment. Best of all, where possible, acquisition strategy and contractual terms should be used to minimize biased inputs and generate credibility. This will be further discussed in subsequent Chapters of this Guide.

A fifth disadvantage is that the DoD is not always able to build its own independent estimate by the Engineered Cost Estimate Method. It must settle often for review of the estimates of potential contractors and comparison with its results from the CER Method.

Within this interim Guide, no detailed procedures are offered for obtaining "Engineered Cost Estimates" of development and production costs. Many methods exist, within Government and industry, for making such estimates. Attempts are constantly being made to improve on these techniques, one example being the cost-to-produce concept. The main thrust of this Guide is to advance the credibility and the use of the O&S costs as part of the system acquisition process, including enhancement of consideration of O&S costs as influences on design and other decisions involved in development and production. This will naturally tend to have an influence on development and production costs. As progress is made in the capability to estimate the latter, future issues of this Guide will promulgate them.

3.6 Realism of Cost Models. There is widespread acceptance of the idea that improved developments and applications of both CERs and Engineered Cost Estimates are needed in order to make the cost aspects of system management more disciplined and more credible, and therefore more reliable as a major contributor to decision-making. These improvements will stem from the policy that cost will henceforth be considered a major design parameter.

Iterative cost estimation is an important part of the process. As the concept and/or the design evolve, feedback to the Government and to involved contractors of the latest cost estimates is essential. This will help to confirm whether certain prospective operational requirements are really cost-effective, and will help to determine whether and how much additional research and development and testing and evaluation are still necessary. Breakdowns of such decisions from the gross level to more specific levels will be facilitated by progressive use of the manageable modules patterned in MIL-STD-881, "Work Breakdown Structure." Motivation of the contractors' judicious efforts along these lines will be enhanced by making the achievement of desired costs (initially, cost estimates; later, cost requirements) a significant part of contractual incentives or award fees.

A DoD publication is currently under preparation, "Cost To Produce Handbook," which describes a formalized system that makes use of iterative cost estimates and feedback. That handbook and this Guide, LCC-3, will be complementary as this Guide provides more detailed attention to the estimating and feedback necessary to make O&S costs suitably influential in the acquisition process.

Increasing use of prototyping is expected to make contributions to the realism of cost estimation and cost control for all system phases, from development through operating and support functions. The use of prototyping will be highly variable across systems. Depending on the prospective benefits, it will vary from use at the level of critical components, sub-systems, or total systems. Whatever the choice, the selected prototype approach will contribute to the realism of the application of cost models so as to make them progressively more accurate.

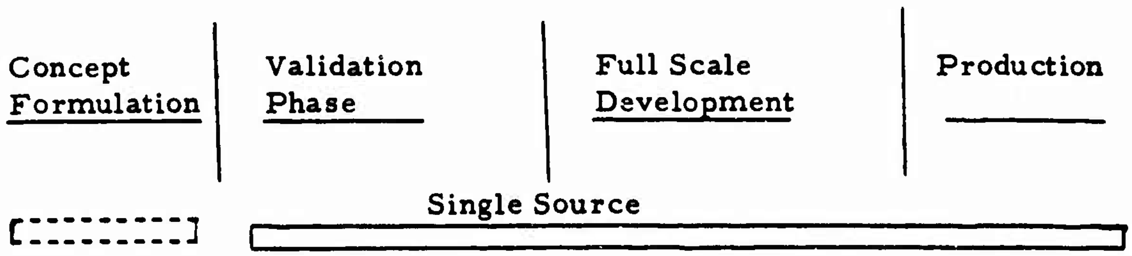
CHAPTER 4

ACQUISITION STRATEGIES AND LCC

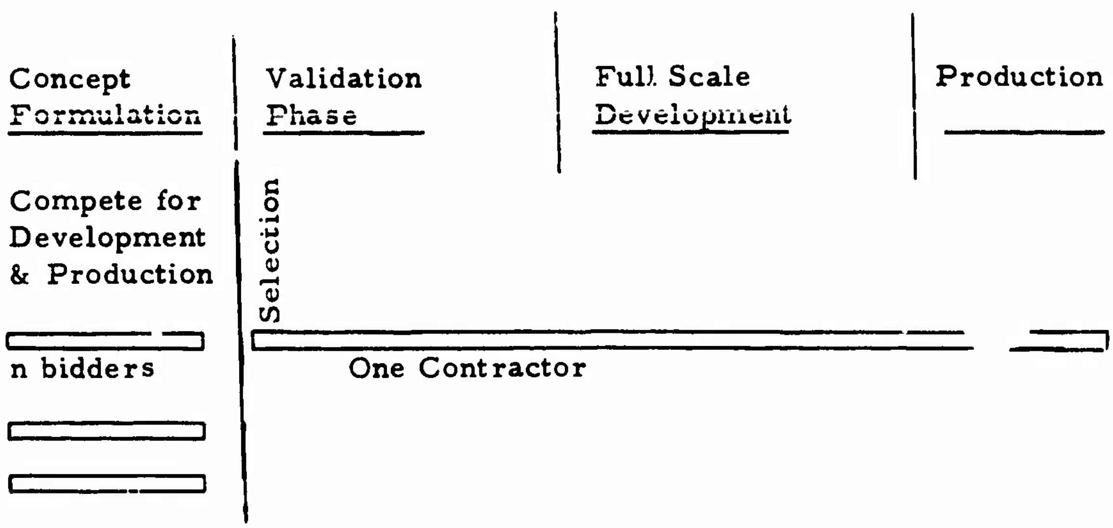
4.1 Various acquisition strategies are followed for bringing new systems into the inventory, and these strategies and their phases influence the decision-making process discussed in Chapter 2. This Chapter covers the application of LCC to various typical strategies.

4.2 Typical Strategies. In the context of this Guide, "strategies" denotes the procedures for handling successive acquisition phases and are differentiated by: the existence of competition; the stage at which multiple bidders are reduced to a single contractor; whether there is competition only at the total system level or for subsystems; whether each phase and/or sub-system is separately contracted for or some are combined under a common contract, and so on. Regardless of whether the strategies are preplanned and deliberate, or are the result of management reactions to events during the acquisition process, LCC warrants application as thoroughly and as effectively as possible for all decisions.

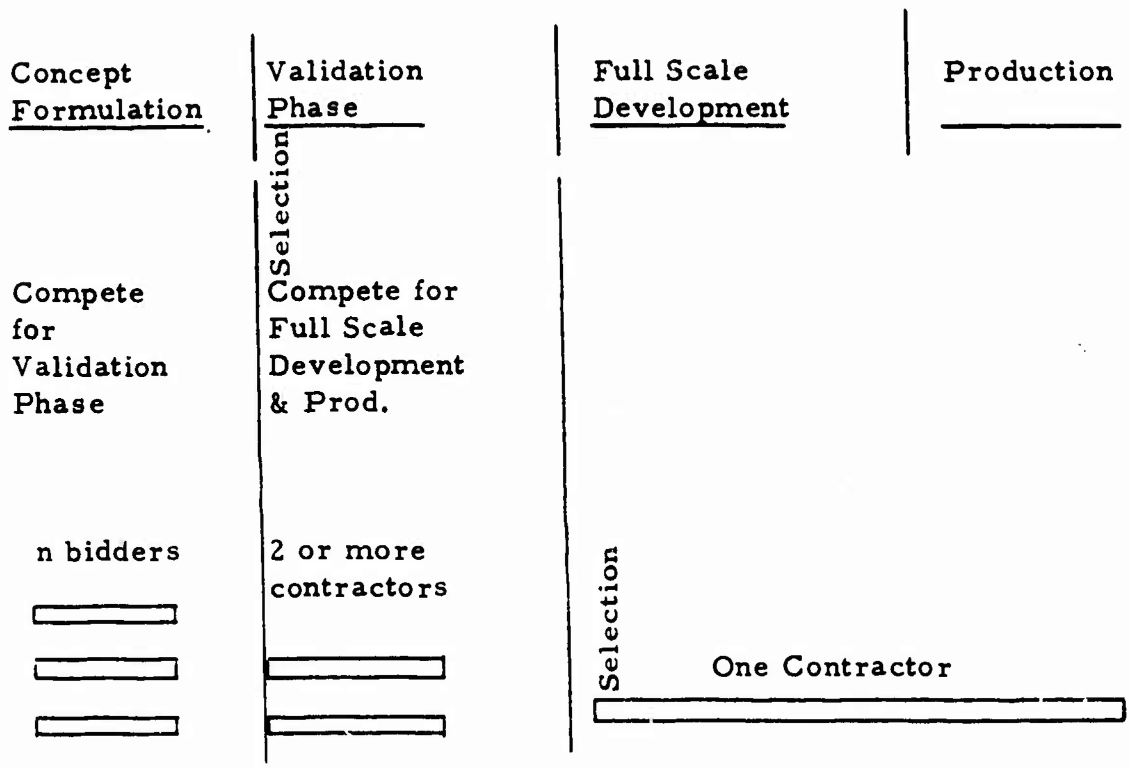
Strategy A. Only one contractor is considered to be equipped to cope with any of the acquisition phases, so that sole source procurement applies throughout (beginning when the Government brings in a contractor and continuing as long as the system remains a viable effort involving a contractor).



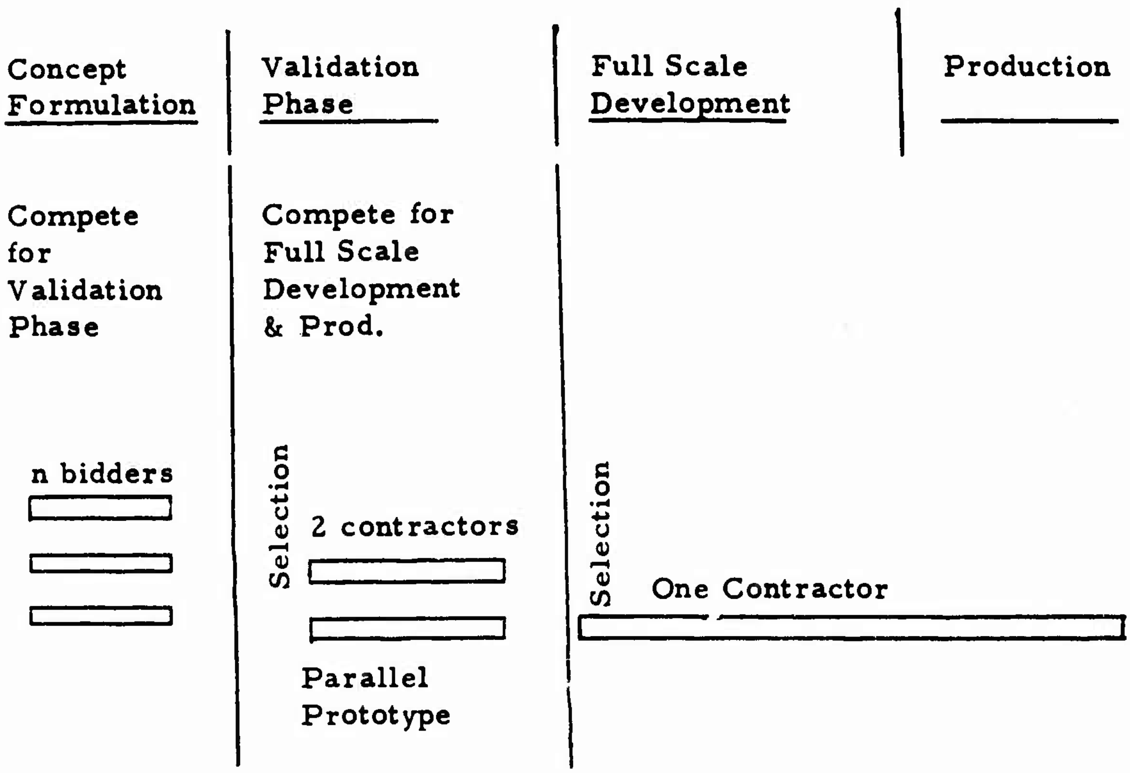
Strategy B. Two or more contractors compete during concept formulation, at the end of which one contractor is selected for the remainder of the program.



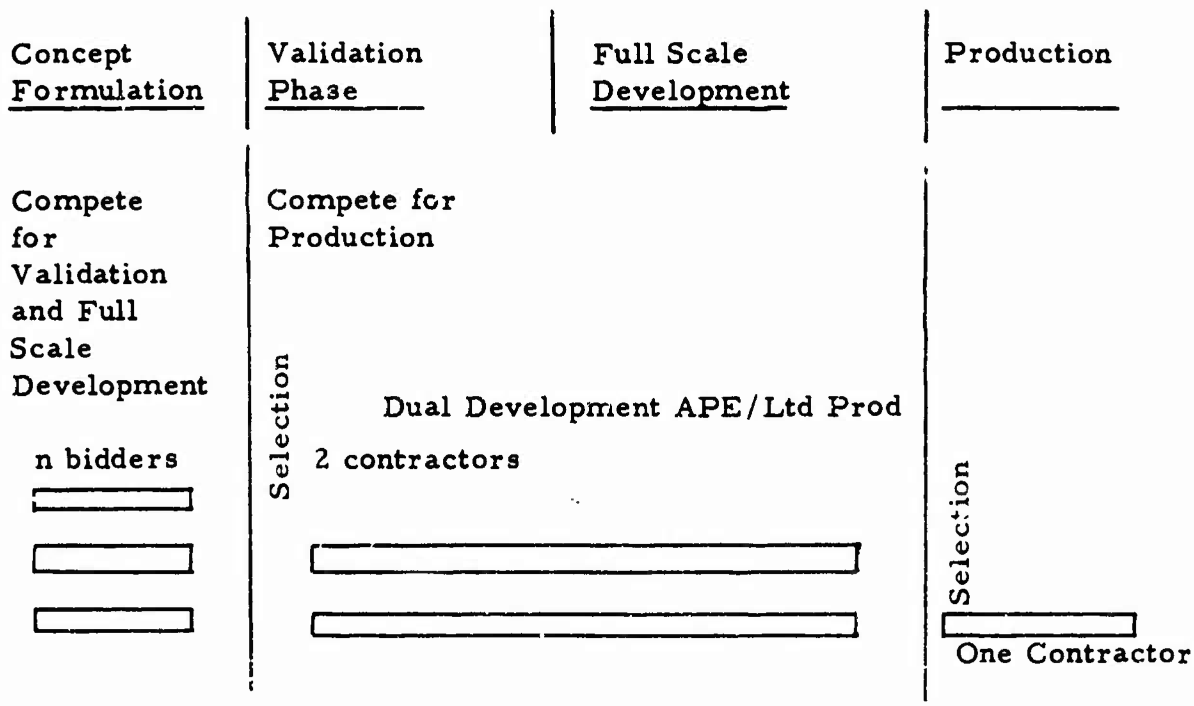
Strategy C. Two or more contractors compete through the validation phase, at the end of which one contractor is selected for the remainder of the program.



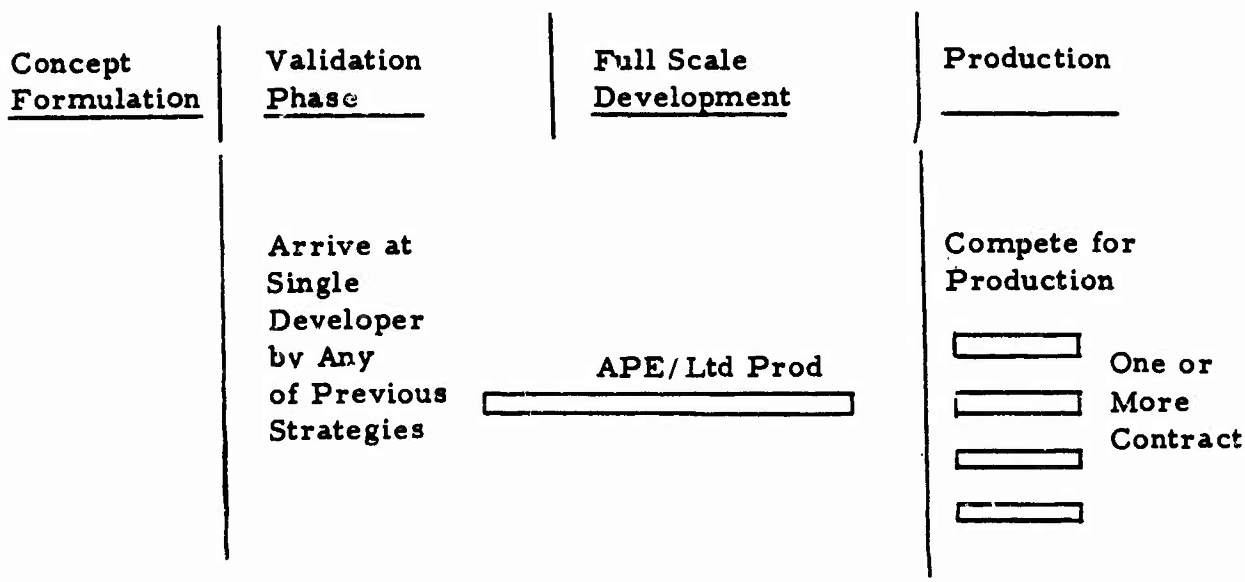
Strategy D. This situation is similar to the preceding strategy except that in this instance parallel prototypes are developed. Following this, one contractor is selected for the remainder of the program.



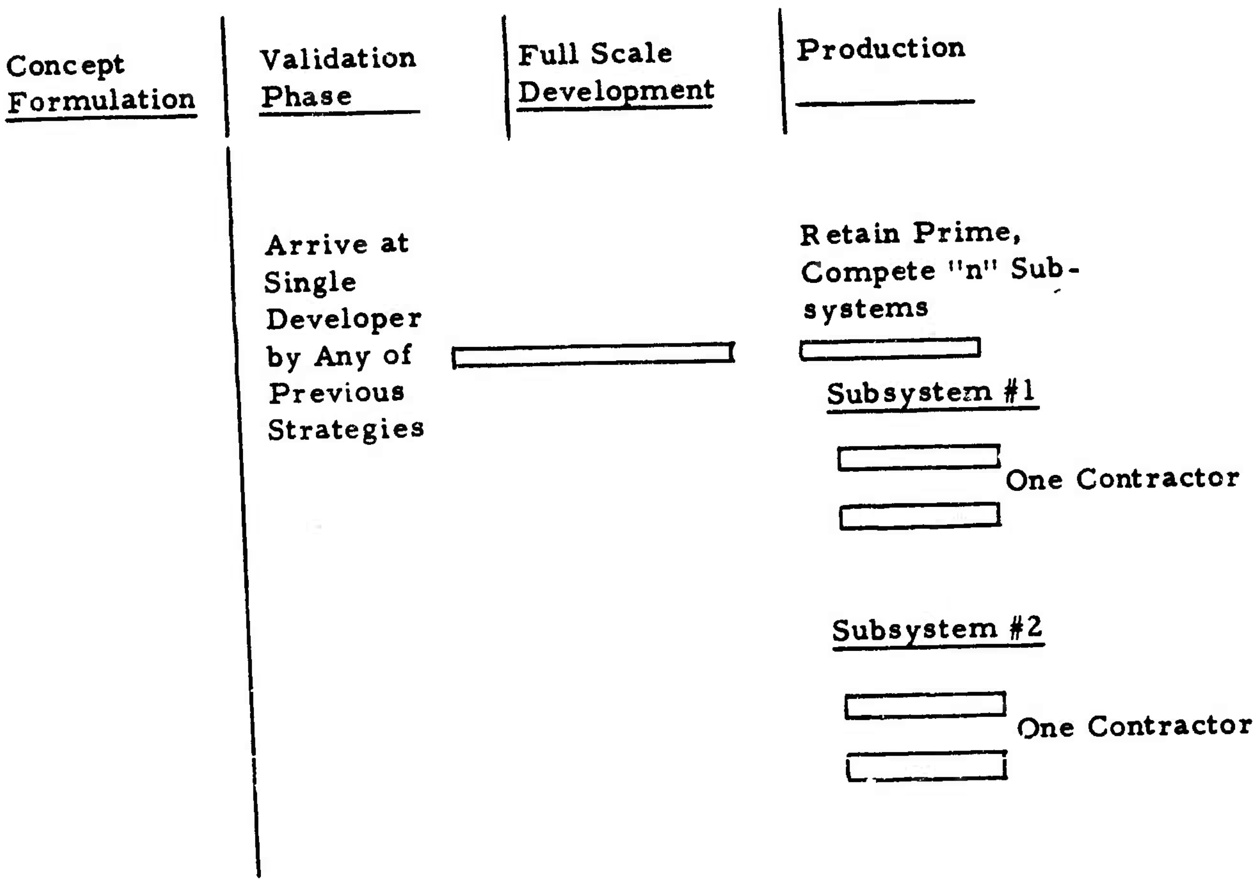
Strategy E. In this instance, there is competition during the concept formulation phase for selection of two contractors to compete through full scale development. Following this, one of the competing contractors is selected for the production phase. This strategy involves advanced production engineering (APE) and limited production of the system by the two competing contractors.



Strategy F. In this instance, a single contractor is selected for advanced production engineering (APE) and limited production, by using any of the previous strategies. Competition would again be employed for selection of a contractor for production of the required quantity.



Strategy G. The same strategies previously presented might be used to select a contractor for any or all phases, except that the Government might elect to competitively purchase "n" subsystems which would become GFE to the prime contractor. (As a variant of Strategy G, parallel efforts may be conducted at the subsystem level during some or all of the phases preceding production.)



4.3 Level of Precision Required. Estimates of LCC should be a factor in most decisions in all phases of all strategies. Thus, while LCC is a consideration across the entire spectrum of decisions involving system acquisitions, whatever strategy is used, the purposes of LCC estimates will vary and the methods used for developing the estimates will also vary.

Greater precision and greater level of detail will progressively be needed as decisions proceed from the earliest and broadest ones to highly detailed decisions. Some of the earlier, broad decisions may involve consideration of improving a current system versus initiating advanced development of a new system; whether to require prototyping or parallel prototyping. Later decisions may involve such questions as whether to incorporate an existing fire control sub-system into a new system, or to develop a new unsophisticated fire control sub-system, or to push the state of the art with a new and sophisticated fire control system. More detailed decisions may involve such questions as whether to achieve appropriate levels of reliability by use of redundant "black boxes," by using redundant circuitry within a black box, or by selective burn-in before assembly of selected black boxes and/or components in them.

The greatest precision is required when the estimates are used as contractual commitments. Thus, it will be noted in Chapter 5 that this Guide, when applied to making contractual commitments, deals with the estimation of LCC only after substantial experience related to a system has been acquired. Before this point is reached, however, there are earlier important decisions that must be made, all of which should involve consideration of LCC.

4.4 DSARC Decisions. In all of the strategies diagrammed above, cost will be a primary consideration in the decisions of the Defense Systems Acquisition Review Council (DSARC). Under certain conditions, for example when funds are extremely limited, short term costs may have a strong influence on these decisions. To the maximum extent practicable, however, DSARC decisions will reflect estimates of LCC, for only on that basis will long term cost-effectiveness be realized.

The earlier DSARC decisions may involve a choice among such options as the following: do nothing; continue exploratory studies; improve an existing operational system; procure an existing system; develop a new system (sometimes using parallel efforts to develop the entire system or important sub-systems).

Subsequent DSARC decisions generally involve a choice among terminating the acquisition, remaining in the existing acquisition phase, or proceeding to the next phase(s).

Because LCC estimates are intended to be used to enhance the decision-making process during all phases of system acquisitions, each bidder and contractor should be informed by provisions in RFPs and contracts that such estimates will be a prime consideration in these decisions.

The DSARC decisions referred to above will require LCC estimation by the CER method during any phase prior to completion of Full-Scale Development, except when, for example, an existing system or sub-system is being procured or parallel prototypes were developed and the Engineered Cost Estimate method can be used. (In all circumstances the most precise method possible should be used.) Thus, the preliminary estimates of life cycle costs required by DoD Directive 5000.1, paragraph III. B. 2, before going into Full-Scale Development will usually be developed by using the CER method. The "acquisition and ownership costs" referred to in paragraph III. B. 3, which are required to be estimated before going into production, will be developed by using the Engineered Cost Estimate method because there is confidence that engineering is complete. At that point in time, operational suitability has been determined by test and evaluation, and data needed for use in the Engineered Cost Estimate method should be available.

4.5 Contractual Commitments. In all of the strategies depicted above, LCC estimates can be expressed as contractual commitments only after completion of Full Scale Development. At this stage the Engineered Cost Estimate method should be used for all final LCC calculations, while CERs may still be used to verify the order of magnitude of the results of the Engineered Cost Estimate method. However, the Government's requirement for such contractual commitments would be equitable only if the bidders and contractors are informed during earlier phases of the acquisition, by provisions in RFPs and contracts, that such commitments may be required.

4.6 Competitive Source Selection. Generally, the earliest use of LCC in source selection decision-making will be after the Validation Phase has been completed. It is not likely that LCC will be a serious consideration in source selection prior to that time because usually it cannot be estimated with sufficient confidence to be reliable and equitable for differentiating among bidders.

In the strategies depicted above, LCC estimates will not ordinarily be a serious consideration during Concept Formulation in selecting a contractor for subsequent phases.

In Strategies C and D, LCC estimates developed by using the CER method should be one of the factors considered in source selection for Full Scale Development and Production. The weight to be given the estimates will depend upon the accuracy of the estimates and the level of confidence in them. It is likely that CERs at this point

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in time will be sufficiently reliable to make the estimates a serious consideration in selecting a contractor, particularly in Strategy D where there is parallel prototyping. Furthermore, in Strategy D there is likely to be sufficient data available to use the Engineered Cost Estimate method to develop some elements of the LCC estimate.

In Strategies E, F and G, LCC estimates developed by the Engineered Cost Estimate method should be used in selecting a contractor for production of the systems (E and F) and the sub-systems (G). These estimates will be developed by the bidders pursuant to criteria in RFPs. They will be verified by the Government and adjusted by mutual agreement, as necessary, and may be incorporated in the production contracts as commitments.

4.7 Other decisions. When practicable, all other decisions should reflect consideration of LCC estimates consistent with available design and operational information. Such decisions are discussed in Chapter 2 and include tradeoffs among design choices, operational procedures, support systems, etc. Throughout the design and development process, cost parameters should be established which consider the cost of acquisition and ownership (LCC) and discrete cost elements of LCC such as unit production cost and operating and support (O&S) cost. Through continuous evaluation these will be translated into design requirements after considering tradeoffs between system effectiveness, cost and schedule. During this iterative process, there should be a gradual transition from CERs to Engineered Cost Estimates.

These estimating techniques are more fully described in Chapter 3. Chapter 5 discusses contract principles for assuring objectivity in these estimates so that the decision process will yield optimal balance between total system cost and total system effectiveness.

CHAPTER 5

CONTRACT PRINCIPLES

5.1 This Chapter discusses contracts where the precedent RFPs require LCC analyses and contracts are awarded on the basis of the analyses, or LCC contractual commitments are required during some phase of the acquisition process.

5.2 <u>Life Cycle Cost Procurement</u>. This term has acquired common usage meaning a procurement which requires consideration of life cycle costs, or relevant segments thereof, in the acquisition process. Generally, the term refers to (i) procurement of major systems or sub-systems where there is competition and life cycle costs, or relevant segments thereof. are quantified in dollars and are a matter of consideration in selecting a source, (ii) procurement of systems or sub-systems when LCC contractual commitments are required during some phase of an acquisition before proceeding to a subsequent phase, for example, from full scale development to production, (iii) competitive procurement of reparable items when relevant segments of life cycle costs are quantified in dollars and award is made on the basis of lowest total cost, (iv) competitive procurement of non-reparable items when the contract award is based on the lowest cost per unit of service life and (v) noncompetitive procurement of items

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when the contractor is required to quote a price for more than one level of reliability, logistics costs are quantified in dollars for each level and award is based on optimum overall cost-effectiveness.

Other circumstances in which the term life cycle cost is considered relevant, not addressed in this Chapter, are (i) non-competitive procurement of items when a pre-solicitation LCC cost analysis is made to determine the source, (ii) design decisions by manufacturers and the Government in the development of major systems, or by the Government in evaluating engineering change proposals, when life cycle costs or segments thereof are used in making a choice among design alternatives, and (iii) the consideration of life cycle costs or segments thereof by the Defense Systems Acquisition Review Council (DSARC) in decisions concerning alternatives to satisfy a defense requirement.

5.3 Advance Notice. When LCC estimates are intended to be used as contractual commitments during any phase of the acquisition process, either for source selection or thereafter, for example before a contractor is authorized to proceed from full scale development to production, bidders and contractors should be informed by provisions in RFPs and contracts that such commitments may be required.

5.4 Credibility. This Guide, when applied to making contractual commitments, deals with the estimation of LCC only after substantial experience related to a system has been acquired. For that particular application, therefore, it avoids those problems intrinsic to premature estimation which are described as "unknown unknowns." In this respect, this interim Guide cannot generally be applied safely for making contractual commitments in the Conceptual or Development phases, or after only paper studies have been performed as in the previously used Definition Phase.

a. In the calculation of operating and support costs, Appendix I to this Guide uses equations which are descriptive in a detailed fashion of the way these costs are actually generated. For example, the equation on cost of pipeline inventories of spares is very close to being an algebraic equivalent of the requirements computations which the military services perform when buying these spares. If some of the cost of the aircraft is attributable to engineering and production costs which reduced failure rates, then inventory spares cost can go down while aircraft cost goes up. The engineering type equations of this Guide can properly reflect this reduced spares cost.

b. There has been some tendency in the past to ask each bidder to devise his own methodology for estimating operating and support costs. The Government knows more than the bidders about the functions being costed here, and about the environment in which they will be performed, and should therefore have more capability than the bidders to state the proper equations, although there might be situations where the bidders might justifiably recommend revisions. Furthermore, the use of Government-furnished equations will mean the bidders are using a standard approach, and will thereby increase their comparability. In addition, it is reasonable to expect that the Government-prescribed costing methodology will avoid certain biases which the competitive environment could generate in contractor-created methodologies. Finally, this Guide's explicit statement of these equations, and adaptive use of them, will subject them to wide exposure and critical review, which will generate progressive refinements so that they will continue to represent the best available methodology for estimating LCC.

c. The values of the variables which are inserted into the cost equations are as important as the equations themselves in determining the cost estimates. Even good equations will produce poor results if they fall prey to poor input values. Here again, biased (i.e., over-optimistic) values might well be expected from bidders unless meaningful deterrence against such bias is provided. A foundation stone of this Guide is its emphasis on contractual discipline, militating against distorted values in the cost equations, without which LCC estimates would not have sufficient credibility.

(1) The Program Manager can help avoid biased inputs by asking the contractors for the detailed values of the many variables which add up to the LCC value. These detailed values can be screened for reasonableness by the various experts who support the Program Manager, and can be adjusted where necessary.

(2) If the Program Manager believes there is substantial uncertainty about some of the important variables, he may also choose to ask for more than one estimate of such variables. Thus, he may require an optimistic and a pessimistic estimate, in addition to the best estimate, or he may require a probability distribution for the possible values. Such augmented data inputs should only be required if the Program Manager has firm, clear plans for their use in source selection or in making other program decisions.

d. In summary, LCC credibility should improve because of the use of standard methodology in the form of Government-prescribed equations; because inputs will come from the most knowledgeable sources, the bidders, at a realistic point in time; because inputs will be made under disciplined arrangements that militate against bias. Furthermore, the application of this Guide and the increased use of LCC will generate improvements in DoD cost data banks, thus improving the basis for LCC estimation in the future.

5.5 LCC Prediction and Verification. The equations in Appendix I, or adaptations thereof, will be exercised first by the bidders[1/] and contractors in a prediction mode and later by the Government in a verification mode. These prediction and verification modes are equally applicable when LCC estimates are required in response to RFPs for use as contractual commitments in source selection and when thereafter, pursuant to provisions in contracts, they are required as contractual commitments before a contractor is authorized to proceed from one phase to another. (It should be noted that RFPs may require LCC estimates which will be one of the factors considered in source selection, but not used as contractual commitments.)

The overall equation for total system LCC may be thought of in terms of two parts:

$LCC_T = LCC_D + LCC_E$, where

LCC_T = total life cycle cost

LCC_D - that portion of LCC which is relevant to the decisions under consideration

LCC_E = that portion of LCC which is excluded in reaching the specific decision, e.g., insignificant costs, sunk costs, and costs that are identical for the alternatives under consideration.

1/ The words "bid(s)" and "bidder(s)" should be understood to include "proposal(s)" and "proposer(s)," i.e., those responding to RFPs.

Costs which are relevant to decisions and contractual commitments treated in this Chapter are represented by LCC_D, and can be further identified as:

$LCC_D = B + C$, where

B = Bid or contract price

C = Cost to the Government of the consequences of selecting the contractor.

Bid or contract price "B" represents money expected to be paid to the contractor. Consequential costs "C" are future costs of ownership incurred by the Government in connection with the contractor's system but which are outside the scope of the contract.

The contractor dominates the environment in which "B" costs are generated. The Government dominates the environment in which "C" costs are generated. Therefore, formulae only for "C" costs are presented in Appendix I.

Costs which are included in "B" in a particular application will be excluded from "C" in that case, even though formulae for such "C-type" costs may be covered in Appendix I. For example, the training costs cited in this Guide will be deleted from "C" if they are included in "B" in a specific contract.

It is anticipated that the "B" costs will generally be contracted for as a firm fixed price, possibly with an incentive provision, whereas the "C" costs will always be handled through an incentive or price adjustment based on quantified achievement. Thus, the equations for the "C" costs will be exercised twice. The first time will be in a prediction mode and will lead to a contractual commitment. The second time, the "C" cost equations will be exercised by the Government in a verification mode, based on system demonstration by the contractor. The comparison of this second calculation of "C" with its value from the initial calculation, the contractual commitment, will be the central feature of the incentive (bonus and/or penalty) determination.

In fairness to both parties the treatment of inflation must be expressed in the contract. The contractor's initial calculation of "C" should be adjusted to reflect the actual inflation rate before comparing it with the second calculation.

5.6 Commitment at the Aggregate Level and Effect on Tradeoffs. The cost elements which comprise "C" will not in general be individually assessed (prediction mode versus verification mode) in a way that influences the dollar flow. Greater flexibility is encouraged by linking dollar payment implications to the total value of "C," rather than to individual cost elements. This permits tradeoffs across hardware aggregations and across different functional cost aggregations to be made more freely, in a continuous search for the least cost alternative. In a broader sense, since choices should be based on consideration of both LCC and System Effectiveness, this refers to a continuous search for that alternative which gives the preferred combination of LCC and System Effectiveness.

Exceptions may be made for any particular elements which the Government wishes to handle separately, in order to impose specific constraints on them. For example, the Government may consider it necessary to impose a minimum acceptable mean-time-between-failures goal on some particularly vital component, and not wish it to be subject to failure tradeoffs with other components; or there may be a ceiling imposed on some cost category which precludes complete flexibility of tradeoffs in favor of other cost categories. Even where such exceptions are involved, efforts should be made to keep the tradeoffs as broad as possible. For example, if each of three critical components could cause an accident, a decision might be made that the maximum failure rate allowable for those components as a group should be one failure in five thousand flying hours. The doors are kept open for future beneficial tradeoffs if these three components are treated as a group, with a maximum allowable group failure rate, rather than a separate rate for each.

5.7 <u>Information on Lower Level Data.</u> Even though contractual dollar implications are linked to aggregate cost estimates, rather than to individual cost elements, the complete rationale substantiating values of individual cost elements will be made available to the Government. This rationale will be used in assessing the credibility of proposals, and will also provide many elements of data useful to the Government for detailed planning of system operation and support, as well as for evaluation of changes. As a part of the rationale the Government may require information relating to the degree of confidence the bidder or contractor has about certain variables, possibly including statistical distributions of their values, or optimistic and pessimistic estimates, along with best estimates. The System Program Manager is encouraged to be selective about such data requirements, going further with them for high impact cost elements, and avoiding large masses of detail possessing low utility.

5.8 Demonstration.

a. It has been indicated previously that demonstrations are a necessary part of LCC contracting. Without demonstrations, bidders and contractors could be motivated to make biased estimates of LCC, and subsequently to make those estimates of LCC which facilitate their most advantageous contract compliance. With demonstrations, this motivation can be converted to cautious optimism and objective risk and cost-effectiveness analyses. For this to happen, the contract must have teeth; the dollar flow from the Government must be closely linked to the achievement of LCC commitments. It is the intent of this Guide to design this linkage in a manner that the decisions made by the contractor, for his greatest benefit, will be the same decisions that will yield the greatest benefit to the Government.

b. The timing and conditions of the LCC demonstration will markedly influence bidders' and contractors' values of LCC. It is very possible that specific, detailed information about the demonstration will be practically as significant as the cost methodology itself in influencing the bidders' and contractors' estimates of LCC costs which will be subjected to the Government's verification process. In brief, the value of LCC estimate will be highly sensitive to a bidder's and contractor's private forecast of his subsequent "achieved value," and this achieved value will be highly sensitive to the timing and the conditions of the demonstration.

c. The demonstrations to be used for LCC verification will be determined by the System Program Manager. There is considerable literature, including many directive type documents throughout DoD, pertaining to test and evaluation. These will be helpful to the Program Manager, but because LCC testing is a new area of endeavor, it is likely that these documents will not offer complete guidance. Furthermore, some of these documents may impose unnecessary constraints. Such matters should be brought to the attention of the appropriate authority for resolution. In general, before making his choices, the Program Manager should be aware of a bidder's or contractor's preferences and reservations in such areas as the following: whether operation and maintenance of equipment will be performed by contractor personnel, by Government personnel, by Government personnel after contractor training, etc.; whether accelerated test conditions will be prescribed for long life items; whether configuration updates will occur before or after these demonstrations; whether parameter values will be taken at their "expected values" or at some other confidence level; whether the LCC demonstrations will be completely integrated with other test programs, partly, or not at all; and so on. Considering the bidder's or contractor's views as well as the Government's views, all demonstration conditions should be as close as possible to an actual operating environment. It is anticipated that the demonstration program required by this Guide will make maximum use of normal test program data and test procedures. Additional requirements for the LCC demonstration will be minimized.

d. There is widespread recognition that test programs have tended to be dropped or diluted as a result of accumulating system problems, whether fiscal or schedule or technical. Application of LCC as visualized in this Guide should be considered as a firm commitment to carry through with the test program to validate the contractor's estimate, as announced in the contract. (It is recognized that it may be necessary, for other purposes, to collect additional similar data outside the framework of the formal LCC test program.) Unless early applications of this Guide are handled in a thoroughly business-like manner, including the testing and monetary consequences thereof, the necessary credibility will not exist to warrant continuing applications.

5.9 Impact on Early Development. This Guide is built upon the assumption that the strongest motivation during design is the contractor's desire to win the production contract. It follows that LCC considerations would be very influential during development and engineering if it is clear that program continuation, or source selection for the subsequent production contract, will be strongly influenced by LCC estimates. Program Managers should assure the clear understanding of this intent by each development contractor. This can be accomplished by incorporating into development contracts descriptions of the basis upon which production contract LCC estimates will be developed and used.

APPENDIX I

OPERATING AND SUPPORT (O&S) COST MODEL

This Appendix contains information needed to interpret and apply typical O&S cost model equations.

I. A. EXCLUDED COSTS

LCC estimates used for making a particular decision, such as source selection or a design choice, need not be the total LCC for the system. As previously discussed, costs which would be the same for each alternative, costs incurred prior to the decision (sunk costs), and costs which would be too small to affect the decision need not be included.

Care must be used in the choice of costs to be excluded lest their omission improperly influences the decisions to be made. For example, consider the case of procuring a relatively inexpensive payload launched by a large booster rocket. It would be tempting to exclude launch vehicle costs because they appear to be common to competing payloads. This would restrict the cost analysis to the tradeoff between the costs and reliability of competing payloads. Exclusion of launch vehicle costs could lead to selection of a cheaper, less reliable payload. But the lower reliabilities of cheaper payloads could generate requirements for a larger quantity of boosters. Thus the assumption on which the booster rocket costs were excluded would prove to be invalid.

Use of the equations in this Appendix to determine LCC effects should consider the interservice effects. For example an LCC evaluation of the F-4 aircraft on a decision that affects both the Navy and the Air Force should consider the F-4 inventory of both the Services.

I. B. ADDITIONAL COST ELEMENTS

The overall equation for total system LCC may be thought of in terms of two parts:

$LCC_T = LCC_D + LCC_E$, where

LCC_T = total life cycle cost

LCC_D = that portion of LCC which is relevant to the decisions under consideration

LCC_E = that portion of LCC which is excluded in reaching the specific decision.

Costs which are relevant to most applications of this Guide are represented by LCC_D, and can be further identified as:

$LCC_D = B + C$, where

B = Bid or contract price

C = Cost to the Government of the consequences of selecting the contractor.

Bid or contract price "B" represents money expected to be paid to the contractor. Consequential costs "C" are future costs of ownership incurred by the Government in connection with the contractor's system but which are outside the scope of the contract.

The equations may be recognized as being incomplete coverage of consequential (C) costs in some particular application. As an example, it may be noted that installation and checkout costs will be incurred for a specific weapon system and are not covered in the equations. The adaptation of this Guide for any application should add additional costs, if they meet the following criteria:

1. They are significant (that is, not too small to warrant the record-keeping and verification efforts).

2. They are not included in the bid price ("B" costs).

3. They are known, or expected, to be different between alternatives (either between bidders, or between decisions that will have to be made by contractors).

4. They are in no way included in the "C" cost equations set forth in this Guide.

I. C. SPECIFIC COST EQUATIONS

This Appendix includes equations and/or instructions for the following:

1. Operational Personnel and Consumables Costs
   a. Personnel
   b. Consumables

2. Training Costs
   a. Initial and Replacement Training
   b. Recurring Training

3. Maintenance Costs
   a. Organizational
   b. Intermediate

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c. Depot (system level)
d. Depot (sub-system or component level)

4. Facilities

5. Initial Government Materiel and Services

6. Support and Test Equipment

7. Data

8. Initial Spares and Repair Parts

9. Salvage and Disposal

10. Initial and Replacement Transportation

11. Supply Management

12. Development and Test

The terms used in the cost equations are defined initially with that equation in which they are introduced in this Appendix. Because it may be difficult to find where a particular variable was introduced, a definition of terms section in alphabetical order is also provided in I.F. beginning at page I-19. Also, refer to I.G. on page I-23 for required input data elements and their sources.

1. OPERATIONAL PERSONNEL AND CONSUMABLES COSTS

a. Personnel

$$COP = \sum_{k=1}^{Y} D_k \sum_{j=1}^{NT} \sum_{s=1}^{NS} (PR_{sjk})(CP_{sj})$$

where:

COP = Life cycle operational personnel cost.

CP_{sj} = Average annual cost (including all pay, allowances, medical care, dental, retirement, etc.) of a man of skill "s" and type "j."

D_k = Discount factor for year "k," to generate a "present value."

NS = Number of combinations of different skills and levels within skills.

NT = Number of types of personnel.

PR_{sjk} = Number of required personnel (including the Government provided factor to account for leave, sickness, etc.) of skill "s" and type "j" in year "k." (Wherever this symbol occurs, it refers to personnel relevant to that equation.)

Y = System operating life cycle (to the nearest year).

j = Type of personnel (civilian/military/etc.).

k = Year in life cycle of the system.

s = Skill type and level.

See paragraph I. C. 3, page I-7, regarding avoidance of double counting of costs where operating personnel perform maintenance.

b. Consumables

$$COC = \sum_{k=1}^{Y} D_k \sum_{i=1}^{NC} (RC_i)(CUC_i)(HC_{ik})$$

where:

COC = Life cycle operational consumables cost.

CUC_i = Cost of operational consumable item "i" per unit consumed, including cost of transportation to point of use.

HC_{ik} = Programmed operational use time (hours of utilization), in year "k"*, of the ships, aircraft, etc., which consume item "i".

NC = Number of consumable items.

RC_i = Consumption rate (units/hour of utilization) of consumable item "i." (Hours of utilization must be compatible with those in HC_{ik}.)

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*The equations regularly compute costs as a function of "operational hours," but could be converted to other program units, such as "miles operated" or "rounds fired" where appropriate.

i = Item number ("i" will be used throughout this Guide to identify consumable and recoverable items).

Other symbols are as previously defined.

Items visualized under the operating consumables category ("i" items) are POL, electrical power, hydraulic/pneumatic power, heating, and cooling energy, nuclear power, and consumable materials. Although the equation is generally applicable to each of these categories, it may require somewhat different inclusions within the specific terms. For example, POL consumption will consider cost per unit of consumption (pounds, gallons, etc.) times utilization hours. In the case of nuclear power, capital outlays may be required at specific dates (e.g., core replacement), and these will be discounted from their respective dates.

2. TRAINING COSTS

a. Initial and Replacement Training

$$CIT = \sum_{k=1}^{Y} D_k \sum_{j=1}^{NT} \sum_{s=1}^{NS} \left[\left(CI_{sj}\right) \left(PR_{sjk} - PA_{sjk} - PF_{sjk}\right) + \left(CU_{sj}\right)\left(PA_{sjk}\right) \right]$$

where:

CIT – Total initial and replacement training cost of personnel.

CI_{sj} = Induction and intial training cost per man (entire cost, including pay and allowances, to bring a man into the service and up to the required skill type and level "s" for personnel type "j").

CU_{sj} = Update training cost per man to bring available personnel up to the required level, for skill type and level "s" and personnel type "j".

PA_{sjk} = Number of available personnel of skill type and level "s" and personnel type "j" that do not require initial training in year "k" but do require up-date training.

PF_{sjk} = Number of personnel of skill type and level "s" and personnel type "j" that are available and fully-trained in year "k".

Other symbols are as previously defined.

Notes:

1. Personnel types and skill levels will include categories cited as operational personnel in Equation 1a, and all other categories used in this system.
2. Also note carefully the definition of PA_{sjk} and PF_{sjk}.
3. Personnel must be available to work on the system under consideration (e.g., not merely available within the Service but assigned to another system).
4. PA_{sjk} and PF_{sjk} variations from year to year include a reflection of turn-over rates.

b. Recurring Training

$$CRT = \sum_{k=1}^{Y} D_k \sum_{j=1}^{NT} \sum_{s=1}^{NS} \left(CR_{sjk}\right)\left(PF_{sjk}\right)$$

where:

CRT = Life cycle recurring training cost

CR_{sjk} = Recurring training cost in year "k" to maintain the proficiency of those personnel working on the system, for skill type and level "s" and personnel type "j."

Other symbols are as previously defined.

Note: The use of PF_{sjk} in the equation for recurring training is based on the premise that those personnel entering the system during year "k" would be fully trained and would not require recurrent training until the succeeding year.

3. MAINTENANCE COSTS

In the maintenance equations below, exclude labor costs for those tasks which are accomplished by operating personnel costed in I.C. 1.a. (Operational Personnel Costs).

a. Organizational

$$CMO = \sum_{k=1}^{Y} (D_k) \left[(HO)(CLO) + CCO + CRO\right] \frac{\left(HUP_k\right)}{HT}$$

where:

CMO = Life cycle material and labor cost for organizational maintenance.

CCO = Total cost of consumable material used in organizational level maintenance during the operational test period. (Includes the cost of items identified as "discard-at-failure.")

CLO = Average organizational level maintenance labor cost per manhour to repair items which were removed during the operational test period (direct and indirect).

CRO = Total cost of recoverable material condemned at the organizational level during the operational test period.

HO = Total maintenance labor manhours used in performing organizational level maintenance during the operational test period.

HT = Total utilization hours of ships, aircraft, tanks, etc., during the operational test period.

HUP_k = Total operational hours of utilization programmed for this entire force of aircraft, ships, tanks, etc., in year "k"

$$= 12 \left[(RUO)(NOU) + (RUT)(NTU) \right]_k$$

where:

NOU = Number of individual operational aircraft, ships, tanks, etc.

NTU = Number of individual training and other non-operational aircraft, ships, tanks, etc.

RUO = Operational utilization rate (hours/month) per aircraft, ship, tank, etc.

RUT = Training and other non-operational utilization rate (hours/month) per aircraft, ship, tank, etc.

Other symbols are as previously defined.

b. Intermediate

$$CMI = \sum_{k=1}^{Y} D_k \left\{ \overbrace{\left[(HI)(CLI) + CCI\right] \frac{HUP_k}{HT}}^{\text{Repair Costs}} + \overbrace{\sum_{i=1}^{NR} CRI_i \left(\frac{HUP_k}{HT}\right)}^{\text{Replenishment Costs*}} + \right.$$

$$\left. \overbrace{\sum_{i=1}^{NR} \frac{(CPI_i)\left(HSI_{i,k} - HSI_{i,k-1}\right)}{HT}}^{\text{Pipeline Costs*}} + \overbrace{\sum_{i=1}^{NR} (NTI_i)(CTI_i)\left(\frac{HUP_k}{HT}\right)}^{\text{Transportation Costs}} \right\}$$

where:

CMI = Life cycle material, labor and transportation cost for intermediate maintenance.

CCI = Total cost of consumable material used in intermediate level maintenance to repair units which were removed during the operational test period.

CLI = Average intermediate level maintenance labor cost per manhour to repair items which were removed during the operational test period (direct and indirect).

CPI_i = Unit acquisition cost of recoverable item "i" multiplied by the number of times that item was removed during the operational test period and ultimately repaired at the intermediate level.

CRI_i = Unit acquisition cost of recoverable item "i" multiplied by the number of times that item was removed during the operational test period and ultimately condemned at the intermediate level.

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*The sum of pipeline costs and replenishment costs (for intermediate and depot levels combined) for each item "i" in any year cannot be less than zero. If negative, replace all terms involved by zero for that item.

CTI_i = Average round trip transportation cost (including packaging, administration and scheduling, from removal to reinstallation) per unit of item "i" removed during the test period and sent to intermediate level, and condemned or repaired at that level.

HI = Total maintenance labor manhours used in performing intermediate level repair on the units that were removed during the operational test period.

$HSI_{i,k}$ = The number of total operating hours for the entire force of aircraft, ships, tanks, etc., programmed during the intermediate repair cycle time for item "i" in the year "k" (where cycle time covers the period of time from removal to reinstallation of item "i", based on first-in, first-out processing).

NR = Number of different recoverable items in the system.

NTI_i = The number of units of item "i" that were removed during the operational test period and sent to the intermediate level, and repaired or condemned at that level.

Other symbols are as previously defined.

c. Depot (System Level)

$$COD = \sum_{k=1}^{Y} 12 \left(D_k\right) \left[\frac{NOU}{MOD} + \frac{NTU}{MTD}\right]_k (COH)$$

where:

COD = Life cycle cost of system overhaul at depot.

COH = Total cost (labor, overhead, round-trip transportation, and material) of individual aircraft, ships, tanks, etc. of each system overhaul.

MOD = Calendar months between overhauls of operational ships, aircraft, tanks, etc.

MTD = Calendar months between overhauls of training and other non-operational ships, aircraft, tanks, etc.

Other symbols are as previously defined.

d. Depot (Sub-system or Component Level)

$$\text{CMD} = \sum_{k=1}^{Y} D_k \Bigg\{ \underbrace{\Big[(\text{HD})(\text{CLD}) + \text{CCD}\Big] \frac{\text{HUP}_k}{\text{HT}}}_{\text{Repair Costs}} + \underbrace{\sum_{i=1}^{NR} \text{CRD}_i \left[\frac{\text{HUP}_k}{\text{HT}}\right]}_{\text{Replenishment Costs*}} +$$

$$\underbrace{\sum_{i=1}^{NR} \frac{(\text{CPD}_i)(\text{HSD}_{ik} - \text{HSD}_{i,k-1})}{\text{HT}}}_{\text{Pipeline Costs*}} + \underbrace{\sum_{i=1}^{NR} (\text{NTD}_i)(\text{CTD}_i)\left[\frac{\text{HUP}_k}{\text{HT}}\right]}_{\text{Transportation Costs}} \Bigg\}$$

where:

CCD = Total cost of consumable material used in depot level maintenance to repair units which were removed during the operational test period.

CLD = Average depot level maintenance labor cost per manhour to repair items which were removed during the operational test period (direct and indirect).

CMD = Life cycle material, labor and transportation cost for depot maintenance at subsystem or component level.

*The sum of pipeline costs and replenishment costs (for intermediate and depot levels combined) for each item "i" in any year cannot be less than zero. If negative, replace all terms involved by zero for that item.

CPD_i = Unit acquisition cost of recoverable item "i" multiplied by the number of times that item was removed during the operational test period and ultimately repaired at the depot (subsystem or component level).

CRD_i = Unit acquisition cost of recoverable item "i" multiplied by the number of times that item was removed during the operational test period and ultimately condemned at the depot (subsystem or component level).

CTD_i = Average round trip transportation cost (including packaging, administration and scheduling, from removal to reinstallation) per unit of item "i" removed during the operational test period and sent to depot level.

HD = Total maintenance labor manhours used in performing depot level repair on the units that were removed during the operational test period.

HSD_{ik} = The number of total system operating hours programmed during the depot repair cycle time for item "i" in year "k" (where cycle time covers the periods of time from removal to reinstallation of item "i", based on first-in, first-out processing).

NTD_i = The number of units of item "i" that were removed during the operational test period and sent to the depot.

Other symbols are as previously defined.

I.D. OTHER COSTS

In addition to the costs for which equations have been presented, the costs of the following should also be included in the weapon system LCC model.

1. FACILITIES

Competing contractors may generate expected LCC differences in Government facilities for production, testing, operations, maintenance and training. Where differences in major facilities are involved, LCC will include the costs of investment, modification, operation, and maintenance of these facilities in support of the system being procured. These costs may be partially covered in the bid price "B" but may also include consequential costs "C".

2. INITIAL GOVERNMENT FURNISHED MATERIEL AND SERVICES

Over and above the bid price (B), additional initial investment costs may be incurred which must be included as a portion of consequential costs (C). An example is costs of differing amounts of Government furnished material or services used by each contractor in his product. The maintenance, operation and support costs associated with this Government furnished material are consequential costs which are included in equations for those functions.

There should be guidelines to the contractors for adding these costs into the total. The initial costs need only be considered when the amounts required differ between bidders. If the particular material needed is no longer in use, and is in idle storage, it should be costed at its salvage value, otherwise the replacement cost should be used. The indirect support costs for GFM and GFE may differ between bidders because of different support approaches even for identical equipments.

3. SUPPORT AND TEST EQUIPMENT

Provisions must be made to include in the consequential costs (C) those initial support and test equipment investment costs which are not contained in the bid price (B) including such data system costs as computer programming and operations. Also the equations used for training, maintenance and operating costs will be applied to support and test equipment as well as prime equipment.

4. DATA

Data costs include both management data (primarily used for cost and schedule control) and technical data (as used for maintenance, reprocurement, configuration control, training, etc.). Consequential costs (C) of data includes such items as printing and distribution not included in bid costs (B).

5. SALVAGE AND DISPOSAL

Procurement based on LCC may require consideration of salvage and disposal (e.g., costs of disposal of nuclear waste material). These costs must be evaluated as to significance in each procurement.

6. INITIAL AND REPLACEMENT TRANSPORTATION

Calculations of costs for transportation of the end item (i.e., aircraft, ship, tank, etc.) to the point of use must be included in the consequential cost (C) if not included in the bid price. Recoverable and consumable item transportation costs are included in the maintenance cost equations.

7. SUPPLY MANAGEMENT

The equations and values for LCC_D will reflect Government prescribed values of the one-time entry cost and the per annum management cost of all new items of supply.

8. DEVELOPMENT AND TEST

Initial total system efforts are being directed toward a case in which any necessary prototyping or parallel development has been completed. However, further development and/or testing related to this procurement may be required which is not included in the bid costs (B) and must therefore be included as part of the consequential costs (C).

9. NOTES

Initial Spares and Repair Parts

The equations for maintenance include the costs of recoverable and consumable spares for both initial stocks and subsequent replenishment.

Discounting

A discounting term, D_k, is included in each equation to permit adjustment of cost to reflect differences in time, and generate a present value.

I.E. EXAMPLE OF EQUATION USAGE

The equations in this appendix show the calculation of major categories of cost. Each equation contains one or more of the following:

- o Cost factors and annual rates that apply to each type/class of resource and/or activity.
- o The arithmetic involved (+, -, ×, ÷) for logical combination of the factors and rates to get annual cost for each type or class.
- o An algebraic summing operation (indicated by Σ), for adding up annual costs of the various types/classes, so that a total annual cost may be derived.
- o Another summation operation (Σ) which adds up the product [total annual costs times the discount rate] for each year of operation. This yields the total discounted cost (i.e., present value) of the particular category, over the operating lifetime of the system.

Some users of this Guide may not have current familiarity with equations of this type. For them the first equation in this appendix will be explained below, and used in a hypothetical example.

1. Explanation of Equation for Operational Personnel Costs (I. C. 1. a.):

(Note: It may be helpful to refer first to the definitions of terms, which follow the equation at the beginning of this appendix.)

$$COP = \sum_{k=1}^{Y} D_k \sum_{j=1}^{NT} \sum_{s=1}^{NS} (PR_{sjk})(CP_{sj})$$

(a) Multiply the number of men (PR) of skill and level 1 (s=1), type 1 (j=1), required in year 1 (k=1), by the annual cost (CP) of such men.

(b) Repeat (a) for each of the other skills and levels (s=2,3,...NS) of type 1 (j=1), and add the results to the result of (a). The result is the total cost of operating personnel of all skills and levels, of type 1 (j=1), in year 1 (k=1).

(c) Repeat (a) and (b) for each of the other types of operating personnel (j=2,3,...NT), and add the results to the result of (b). The result is the total cost of operating personnel of all types (civilian, military,...), and all skills and levels (pilot, navigator, etc.; lieutenant, ... , captain, etc.) in each type, for year 1 (k=1).

(d) Multiply the total personnel cost of year 1 by the discount factor (D) for year 1 (k=1). Now we have the present value of the total cost of operating personnel for year 1 (k=1).

(e) Repeat (a) through (d) for each of the subsequent years (k=2,3,... Y), and add the results to the result of (d). The result is the total cost of operating personnel, over the life cycle of the system (Y years), all discounted to a present value.

The letters (a) through (e) above correspond with the letters that are used in 2b(2) below.

2. EXAMPLE

Equation for Operational Personnel Costs (I. C. 1. a.):

$$COP = \sum_{k=1}^{Y} D_k \sum_{j=1}^{NT} \sum_{s=1}^{NS} (PR_{sjk})(CP_{sj})$$

a. Illustrative Case

A personnel transport helicopter

(1) 2 units per base
(2) 50 bases worldwide.
(3) 2 operators

	Annual Cost
one pilot per vehicle (military)	\$25,000
one copilot/engineer per vehicle (military)	\$22,000
2 ground service personnel	
one lead man per vehicle (military)	\$15,500
one attendant per vehicle (civilian)	\$10,500

(4) 10 years operating life for the helicopter.
(5) Items (1) through (3) above apply for each of the 10 years of operation.

b. Calculation of COP

(1) Setting of indexes s, j, and k contained in above equation.

Number of types of personnel (NT) = 2

Type, military:		j = 1
3 skills/levels, (NS=3)	pilot	s = 1
	copilot	s = 2
	ground service leadman	s = 3
Type, civilian:		j = 2
1 skill & level, (NS=1)	ground service attendant	s = 1
For Operating Years 1, 2, ... 10, (Y=10), set and increment values of k accordingly		k = 1, 2, ... 10

(2) Calculations, in sequence as shown in paragraph I. E. 1. above -

(Total vehicles worldwide = 50 x 2 = 100)

(a) j = 1, all Military Types; k = 1, in year 1

s = 1, Cost of Pilots: $(PR_{1,1,1})(CP_{1,1})$

(1 pilot per vehicle x 100 vehicles)(25,000 per pilot) = \$2,500,000

(b) s = 2, Cost of Copilots: $(PR_{2,1,1})(CP_{2,1})$

(1 x 100) (22,000) = \$2,200,000

$s = 3$, Cost of ground service lead man: $(PR_{3,1,1})(CP_{3,1})$

$(1 \times 100)(15,500) = \$1,550,000$

SUB TOTAL = $6,250,000

(c) $j = 2$, All Civilian Types

$s = 1$, Cost of ground service attendant:

$(PR_{1,2,1})(CP_{1,2})$

$(1 \times 100)(10,500) = \$1,050,000$

SUB TOTAL = $1,050,000

Total Cost of Operational Personnel in Year 1: $7,300,000

(d) Discounting the total cost of year 1 (at a rate of 10%, ref: DOD Inst. 7041.3, Encl. 2, Att. 4, Table A):

Year	Total Cost in Year k		Discount Factor For Year k		Present Value of Cost in Year k
k	$\sum_{j=1}^{NT} \sum_{s=1}^{NS} (PR_{sjk})(CP_{sj})$	×	D_k	=	COP subtotal
1	$7,300,000	×	.954	=	$6,964,200

(e) Repeat for years 2 through 10:

2	$7,300,000	.867	=	$6,329,100
3	$7,300,000	.788	=	$5,752,400
4	$7,300,000	.717	=	$5,234,100
5	$7,300,000	.652	=	$4,759,600
6	$7,300,000	.592	=	$4,321,600
7	$7,300,000	.538	=	$3,927,400
8	$7,300,000	.489	=	$3,569,700
9	$7,300,000	.445	=	$3,248,500
10	$7,300,000	.405	=	$2,956,500

Total Life Cycle Cost of Operational Personnel, Discounted to Present Value (COP) = $47,063,100

I.F. DEFINITION OF TERMS

CCD = Total cost of consumable material used in depot level maintenance to repair units which were removed during the operational test period.

CCI = Total cost of consumable material used in intermediate level maintenance to repair units which were removed during the operational test period.

CCO = Total cost of consumable material used in organizational level maintenance during the operational test period. (Includes the cost of items identified as "discard-at-failure")

CI_{sj} = Induction and initial training cost per man (entire cost, including pay and allowances, to bring a man into the service and up to the required skill type and level "s" for personnel type "j").

CIT = Total initial and replacement training cost of personnel.

CLD = Average depot level maintenance labor cost per manhour to repair items which were removed during the operational test period (direct and indirect).

CLI = Average intermediate level maintenance labor cost per manhour to repair items which were removed during the operational test period (direct and indirect).

CLO = Average organizational level maintenance labor cost per manhour to repair items which were removed during the operational test period (direct and indirect).

CMD = Life cycle material, labor and transportation cost for depot maintenance at subsystem or component level.

CMI = Life cycle material, labor and transportation cost for intermediate maintenance.

CMO = Life cycle material and labor cost for organizational maintenance.

COC = Life cycle operational consumables cost.

COD = Life cycle cost of system overhaul at depot

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COH = Total cost (labor, overhead, round trip transportation, and materiel) of individual aircraft, ships, tanks, etc. of each system overhaul.

COP = Life cycle operational personnel cost.

CP_{sj} = Average annual cost (including all pay, allowances, medical care, dental, retirement, etc.) of a man of skill "s" and type "j."

CPD_i = Unit acquisition cost of recoverable item "i" multiplied by the number of times that item was removed during the operational test period and ultimately repaired at the depot (subsystem or component level).

CPI_i = Unit acquisition cost of recoverable item "i" multiplied by the number of times that item was removed during the operational test period and ultimately repaired at the intermediate level.

CR_{sjk} = Recurring training cost in year "k" to maintain the proficiency of those personnel working on the system, for skill type and level "s" and personnel type "j."

CRD_i = Unit acquisition cost of recoverable item "i" multiplied by the number of times that item was removed during the operational test period, and ultimately condemned at the depot (subsystem or component level).

CRI_i = Unit acquisition cost of recoverable item "i" multiplied by the number of times that item was removed during the operational test period, and ultimately condemned at the intermediate level.

CRO = Total cost of recoverable material condemned at the organizational level during the operational test period.

CRT = Life cycle recurring training cost.

CTD_i = Average round trip transportation cost (including packaging, administration and scheduling, from removal to reinstallation)per unit of item "i" removed during the operational test period and sent to depot level.

CTI_i = Average round trip transportation cost (including packaging, administration, and scheduling, from removal to reinstallation)per unit of item "i" removed during the test period and sent to intermediate level, and condemned or repaired at that level.

CU_{sj} = Update training cost per man to bring available personnel up to required level, for skill type and level "s" and personnel type "j."

CUC_i = Cost of operating consumable item "i" per unit consumed, including cost of transportation to point of use.

D_k = Discount factor for year "k" to generate a "present value."

HC_{ik} = Programmed operational use time (hours of utilization), in year "k", of the ships, aircraft, etc., which consume item "i".

HD = Total maintenance labor manhours used in performing depot level repair on the units that were removed during the operational test period.

HI = Total maintenance labor manhours used in performing intermediate level repair on the units that were removed during the operational test period.

HO = Total maintenance labor manhours used in performing organizational level maintenance during the operational test period.

HSD_{ik} = The number of total system operating hours programmed during the depot repair cycle time for item "i" in year "k" (where cycle time covers the period of time from removal to reinstallation of item "i", based on first-in, first-out processing).

HSI_{ik} = The number of total operating hours for the entire force of aircraft, ships, tanks, etc. programmed during the intermediate repair cycle time for item "i" in year "k" (where cycle time covers the periods of time from removal to reinstallation of item "i", based on first-in, first-out processing).

HT = Total utilization hours of ships, aircraft, tanks, etc., during the operational test period.

HUP_k = Total operational hours of utilization programmed for this entire force of aircraft, ships, tanks, etc., in year "k."

i = Item number ("i" will be used throughout this Guide to identify consumable and recoverable items).

j = Type of personnel (civilian/military/etc.).

k = Year in life cycle of the system.

MOD = Calendar months between overhauls of operational ships, tanks, aircraft, etc.

MTD = Calendar months between overhauls of training and other nonoperational ships, tanks, aircraft, etc.

NC = Number of consumable items.

NR = Number of different recoverable items in the system.

NOU = Number of individual operational aircraft, ships, tanks, etc.

NS = Number of combinations of different skills and levels within skills.

NT = Number of types of personnel.

NTD_i - The number of units of item "i" that were removed during the operational test period and sent to the depot.

NTI_i = The number of units of item "i" that were removed during the operational test period and sent to the intermediate level, and repaired or condemned at that level.

NTU = Number of individual training and other nonoperational aircraft, ships, tanks, etc.

PA_{sjk} = Number of available personnel of skill type and level "s" and personnel type "j" that do not require initial training in year "k," but do require update training.

PF_{sjk} = Number of personnel of skill type and level "s" and personnel type "j" that are available and fully-trained in year "k."

PR_{skj} = Number of required personnel (including the Government provided factor to account for leave, sickness, etc.) of skill "s" and type "j" in the year "k." (Whenever this symbol occurs, it refers to personnel relevant to that equation.)

RC_i = Consumption rate (units/hour of utilization) of consumable item "i." (Hours of utilization must be compatible with those in HC_{ik}.)

RUO = Operational utilization rate (hours/month) per aircraft, ship, tank, etc.

RUT = Training and other nonoperational utilization rate (hours/month) per aircraft, ship, tank, etc.

s = Skill type and level.

Y = System operating life cycle (to the nearest year).

NOTE: In all definitions above, the word "average" should be taken to be the arithmetic mean, excluding exceptional non-recurring values.

I. G. LIFE CYCLE COSTING DATA ELEMENTS

Item No.	Data Elements	Value	Units	Comments	Data Source
1	CCD-Depot CCO-Organ. CCI-Intermediate		\$ \$ \$		Cont.
2	CI_{sj}		\$		DOD
3	CLD-Depot CLI-Intermediate CLO-Organ.		\$/hour \$/hour \$/hour		DOD
4	COH		\$		Cont./DOD
5	CP_{sj}		\$/year		DOD
6	CPD_i		\$		Cont.
7	CR_{sj}		\$		Cont.
8	CRD_i CRI_i CRO		\$ \$ \$		Cont.

Item No.	Data Elements	Value	Units	Comments	Data Source
9	CTD_i-Depot CTI_i-Intermediate		\$/item \$/item		DOD
10	CU_{sj}		\$		Cont.
11	CUC_i CPI_i		\$ \$	Cont. should use DOD supply system costs where available	Cont.
12	D_k		-		DOD
13	HC_{ik}		hrs/yr	Subject to DOD guidelines	Cont.
14	HD-Depot HI-Intermediate HO-Organ.		hours " "		Cont.
15	HSD_{ik} HSI_{ik}		hours hours		DOD
16	HT		hours		DOD
17	MOD MTD		mos. "	Subject to DOD guidelines	Cont.
18	NC NR		-		Cont.
19	NTD_i-Depot NTI_i-Intermediate		units "		Cont.
20	NOU NTU		units "	Subject to DOD guidelines/ DOD reclama	Cont.
21	PA_{sjk}		pers.		DOD
22	PR_{sjk}		pers.	Subject to DOD guidelines	Cont.
23	RC_i		units/hr		Cont.
24	RUO RUT		hrs/mo hrs/mo	Subject to contractor reclama	DOD
25	Y		yrs		DOD

NOTE: Many of the items marked for contractor responsibility will require DOD/ Contractor cooperation for data assembly during the test period.

APPENDIX II

OPERATING AND SUPPORT (O&S) COST DATA SOURCES

Cost data on development, acquisition, operating and support of weapon systems, sub-systems, or components are available in varying degrees within the individual Services.

Since at the present time no service has a system which routinely collects total operating and support costs for all primary weapon systems at all levels of support, existing data are generally the result of special studies or analyses directed at collecting performance and cost data for specific systems, and oftentimes on a sample basis. This condition is expected to continue for several years pending implementation of equipment performance and cost systems currently being introduced into the Military Departments.

Nevertheless sufficient data do exist to be helpful in many instances as a basis for parametric estimating (Cost Estimating Relationships). Much of the data include factors which, though carefully determined, cannot be verified with actual cost data. Since the factors have been prepared by individual sources familiar with the subject they are generally considered to have a high degree of confidence. As a general rule, the data are not prepared or available at a central source and it is therefore necessary to search out the specific data required. Representative sources are the following:

ARMY

a. The CER Compendium for Army Weapon and Equipment Systems prepared by the Office of the Comptroller, Hqs, U. S. Army Materiel Command, Washington, D. C.

b. The U. S. Army Major Item Data Agency, Letterkenny Army Depot, can provide from an automated data bank, special data outputs relative to depot overhaul, and, for selected items, can provide overhaul cost data/man-hours for overseas depots and contract overhaul.

c. Certain information in support of life cycle cost estimating for an end item of equipment can be provided on an as required basis from data available in the AMC Logistic Data Center's data bank. The information is received primarily from organizational, direct, and general support activities and is limited to those end items of equipment selected for reporting of maintenance accomplishments. Requests for this information should be addressed to:

Headquarters, U. S. Army Materiel Command
Washington, D. C. 20315
ATTN: AMCMA-SE

Since the scope of the reporting requirement was sharply reduced in 1969 data available is subject to the following restrictions:

(1) Operating and Support data reflecting age, usage, man-hours and parts replacement are available as reported and recorded in the AMCLDC data bank from the organizational level for the period October

1965 to October 1969. Data elements reported from support level cover the period from October 1965 to October 1970.

(2) Age distribution information on combat and tactical vehicles identified in Appendix C of TM 38-750 is available from August 1969 to present. (Information on TM 38-750 can be obtained by requisition on DA Form 17 forwarded to:

U. S. Army AG Publications Center
1655 Woodson Road
St. Louis, Missouri 63144)

(3) More current operating and support data reflecting age, usage, parts, man-hours, and POL consumption can be provided on items nominated and approved by DA for sample data collection. At present this applies to a very limited number of items.

d. The U. S. Army Field Operating Cost Agency (Hoffman Building, Alexandria, Virginia) can provide extensive operating and support cost data, but only on a very limited number of weapons.

e. Training cost data by MOS is available from Hqs, CONARC, Attn: DSC COMPT-C and EA, Fort Monroe, Virginia.

NAVY

Within the Navy no central repository currently exists containing complete and reliable historical data for operating and support costs.

To estimate life cycle cost by the CER method, the Navy programmer must develop his CERs using data from one or more sources.

Some of these sources for data and CERs include:

a. NAVY PROGRAM FACTORS, OPNAV 90P-02, contains investment, personnel and maintenance average costs by ship and aircraft type. These can be obtained from:

Director, General Planning and Programming Division
Navy Department
Washington, D. C. 20350
ATTN: OP-904

b. 3M Data at Maintenance Supply Office (MSO), contains maintenance data to all levels of equipment and component indenture. These can be obtained from:

Maintenance Support Office (MSO)
Mechanicsburg, Pennsylvania 17055

(Refer to NAVMATINST 4790.7 of 23 April 1970, Subject: Navy 3M System Information Reports from MSO; Procedures for Requesting.)

c. NAVCOMPT Manual, available at all Naval activities, contains composite standard military rates for costing of military personnel services.

d. Navy Military Manpower Billet Cost Data for Life Cycle Planning Purpose, NAVPERS 15163, describes a billet costing model for Navy Personnel. These can be obtained from:

Bureau of Naval Personnel
Navy Department
Washington, D. C. 20370
ATTN: PERS A3A

e. Ship Manning Document Process (SMD), a model for ship manning computerized by BUPERS on IBM 360-65. The data are on hand at the Navy Manpower and Material Analysis Command, a field activity of CNO (OP-12). Related documents include:

(1) Guide to Preparation of Ship Manning Documents (SMD), Vol. I, OPNAVPUB 10-P23.

(2) U. S. Navy Guide for Preparation of Ship Manning Documents (SMD), Vol. II, Documentation and Development Procedures, OPNAVPUB 12-P4.

Volumes I and II can be obtained from:

Chief of Naval Operations
Navy Department
Washington, D. C. 20370
ATTN: OP-12

f. Departure Reports from Naval Shipyards and Performance Reports from Naval Air Repair Facilities. Thest must be obtained from the respective Naval Shipyard or Naval Air Repair Facility.

The Naval Ship Engineering Center (NAVSEC 6112) will develop CERs and estimate life cycle costs for Ship Acquisition Project Managers upon request. The Project Manager furnishes all known ship parameters to NAVSEC with the request to develop a life cycle cost estimate. The NAVSEC personnel develop a LCC model by scaling the specific ship's parameters to known similar type ship CERs and related historical O&S data.

The Naval Air Systems Command (AIR-501) will furnish life cycle costs to Aircraft Acquisition Project Managers upon request. Upon receipt of the aircraft's particular parameters a LCC estimate is obtained from a computerized model at the Naval Air Development Center, Johnsville. The System Cost and Operational Resource Evaluator (SCORE) LCC model is designed to operate from statistically derived data and is a versatile and flexible model easily adapted to meet most needs. The statistical base is regularly updated by NAVAIR Logistics codes.

Other existing CERs for specific aircraft sub-systems and for gross application are available from NAVAIR.

AIR FORCE

In the Air Force, documents containing information on procurement cost factors for (1) operation and manning, (2) fuel, (3) depot and base maintenance, (4) replenishment spare parts, (5) training, (6) modification, etc., are:

a. AFM 172-3, "USAF Cost and Planning Factors." This can be obtained from:

Headquarters, U. S. Air Force
AF/ACMC
Washington, D. C. 20330
(Provide written justification with request.)

b. TACM 178-2, "TAC Factors and Standards Manual." This can be obtained from:

Hq, Tactical Air Command
(ACM)
Langley Air Force Base, Virginia 23365

c. NORAD Cost Factors and Systems Data Book. This can be obtained from:

Hq, NORAD
(NPPF)
Air Defense Command
Ent Air Force Base, Colorado 80912

Additional sources are the USAF Force and Financial Program and HQ USAF Cost Library, Hq, USAF, AF/ACMC, Washington, D. C. 20330, and the AFSC Cost Library, Hq, Air Force Systems Command, AFSC/ACCE, Andrews Air Force Base, Maryland 20331.

APPENDIX III

REPRESENTATIVE DOCUMENTS PERTAINING TO CERs

Cost Considerations in Systems Analysis, by Gene H. Fisher, RAND Corporation, 1970. RAND No. R-490-ASD.

Military Equipment Cost Analysis, by the RAND Corporation, June 1971 - prepared for OASD(SA), and not to be shown to contractors or their agents because of inclusion of privileged information. Defense Documentation Center No. AD 901 477L.

An Introduction to Equipment Cost Estimating, by the RAND Corporation (Memorandum RM-6103-SA, December 1969) prepared for OASD(SA). Defense Documentation Center No. AD 702 424.

Cost Estimating Methods for Ground Combat Surveillance Radars, April 1968, B. C. Frederic, et al, General Research Corporation. Defense Documentation Center No. AD 848 575.

Cost Evaluation and Cost Estimating for Shipboard Electronic Equipment - Volume II: Development of Cost Estimating Relationships, April 1967, H. Dagen, et al, ARINC Research Corporation. Defense Documentation Center No. AD 833 945.

Prediction of Development Costs for Large Radar Systems, August 1967, H. Balaban, et al, ARINC Research Corporation. Defense Documentation Center No. AD 820 143.

Methods of Estimating Fixed Wing Airframe Costs, Planning Research Corporation, PRC R-547A, Volume I, Unclassified, Defense Documentation Center No. AD 817 670 and Volume II, Confidential, Defense Documentation Center No. AD 384 318 Prop.

Helicopter Man-Hours and Cost Estimating Relationships, March 1967, G. P. Ward, OASD(System Analysis), For Official Use Only. Defense Documentation Center No. AD 873 391L.

Costs of Operation and Maintenance Activities (Army): Techniques for Analysis and Estimation, January 1968, John G. Phillips, Research Analysis Corporation, RAC-TP-242. Defense Documentation Center No. AD 664 748.

Cost Estimating Relationships: A Manual for the Army Materiel Command, May 1972, Alfred D. Stament and Carl R. Wilbourn, Research Analysis Corporation, RAC-TP-449. Defense Documentation Center No. AD 742-810.